OTH-B RADAR

Environmental Impact Analysis Process

Draft Environmental Impact Statement
Proposed
Central Radar System
Over-the-Horizon Backscatter Radar Program
August 1986

DEPARTMENT OF THE AIR FORCE
AIR FORCE SYSTEMS COMMAND
ELECTRONIC SYSTEMS DIVISION

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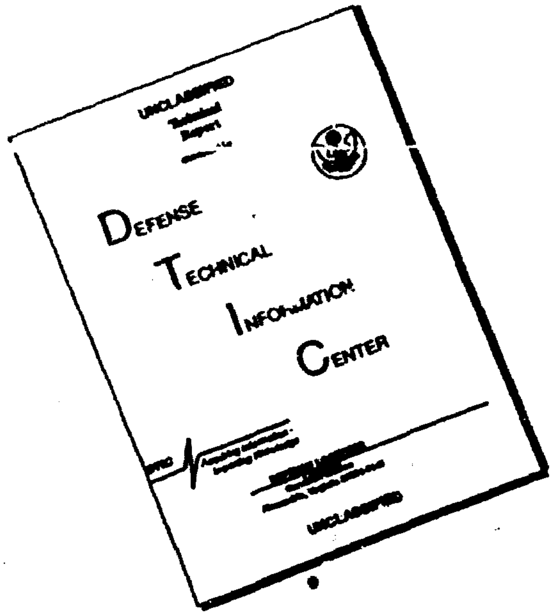

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Jack Bush, GM-14
Mr. Jack Bush
Special Projects and Plans
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COVER SHEET

(a) Responsible Agency: U.S. Air Force

(b) Proposed Action: Construction and operation of the Central Radar System, an Over-the-Horizon Backscatter (OTH-B) radar system that would be located in the north central region of the U.S.

(c) Responsible Individual: Lt. V. G. Brown
ESD/SCO
Hanscom AFB, MA 01731
(617) 271-5360

(d) Designation: Draft Environmental Impact Statement (DEIS)

(e) Abstract: This document describes the probable environmental impacts of constructing and operating a new surveillance and tracking radar that operates in the High-Frequency band of the electromagnetic spectrum. The radar system would consist of four very large transmit antenna arrays located in either northeastern South Dakota or west-central Minnesota, four larger receive antenna arrays located in either eastern North Dakota or northwestern Minnesota, and an operations center proposed for Grand Forks Air Force Base, North Dakota. Five areas were considered for the transmit arrays, four areas for the receive arrays, and one site for the operations center. Potential significant physical and biological impacts can be avoided or minimized by careful selection of the transmit and receive sites. The key concerns are erosion in areas where substantial grading would be required, interruption of water courses and drainage patterns, disturbance of migratory bird habitat, and the potential for birds colliding with the antennas. Moderate economic stimulation of local economies would result from construction activities, but the benefits of continuing operations would be small. Electromagnetic interference with telecommunication systems is unlikely. No reliable evidence exists that chronic exposure of humans to the radiofrequency radiation levels outside the exclusion fence surrounding the transmit site is likely to be harmful.

(f) Released to the public August 15, 1986. All written comments pertaining to this DEIS must be received by October 6, 1986.

SUMMARY

DRAFT ENVIRONMENTAL IMPACT STATEMENT
Construction and Operation of the Central OTH-B Radar System

Description of the Action

The Over-the-Horizon Backscatter (OTH-B) radar is a surveillance and tracking radar system that the U.S. Air Force plans to construct and operate at four locations in the United States. The functions of these radar systems are to detect, track, and give early warning of aircraft and cruise missiles approaching North America. Early warning of hostile aircraft approaching North America is critical to the defense of the United States.

The four planned OTH-B systems would establish a surveillance zone around the east, west, and south perimeters of North America. The Central Radar System (CRS) is needed to complete the perimeter coverage of the southern approaches to North America. It is also needed to cover the near-shore ocean areas not covered by the East Coast and West Coast OTH-B systems.

The functional components of the CRS would be geographically separated from one another: Different sites would be required for the transmit and receive antennas; the operations center, which would process radar data, would be separate from both of those sites. Four areas in eastern North Dakota (known as the Dahlen, Goose River, Galesburg, and Blanchard study areas) and one in northwestern Minnesota (Thief River Falls study area) were studied for the receive site. Three areas in west-central Minnesota (Wheaton N, Wheaton SE, and Wheaton SW) and one in northeastern South Dakota (Amherst) were studied for the transmit site. Grand Forks Air Force Base, North Dakota, is the proposed location of the operations center.

The OTH-B transmitters and receivers use very large fixed antennas. The transmit site and the receive site would each require a minimum of about 2,400 acres. The operations center would be housed in a conventional building of about 48,000 ft^2. Approximately 50 maintenance and security personnel would be required at the transmit site and at the receive site; about 390 operating personnel would be located at the operations center.

Public Concerns

In conformance with the requirements of the Council on Environmental Quality, the Air Force convened a series of 10 scoping meetings in communities near the areas studied and in the North and South Dakota and Minnesota state capitols. Many questions about the characteristics and features of the radar system and its construction were asked. At the request of citizens seeking more information, Air Force personnel have subsequently conducted telephone conversations and held additional meetings. During these various exchanges, concerns were expressed about:

- The impacts of construction and operation, particularly on property tax revenue, on the infrastructure (especially roads), and on birds and their migration
- The land requirements for sites, and the process and basis for acquiring land
- The biological effects of radiofrequency radiation (RFR)
- The use of land already in federal control
- Electromagnetic interference, primarily with radio and television
- The loss of agricultural land
- Superior alternative surveillance systems
- Restrictions on aircraft operations
- Increased aircraft or ground vehicle traffic
- Site selection and environmental analyis processes
- Job opportunities and required training
- OTH-B as a military target.

Environmental Effects

Biophysical Effects

The areas studied for the transmit and receive sites are largely farmland. Generally, the areas have poorly drained soils, and they are characterized by numerous temporary and permanent streams and potholes. Wetlands frequently surround the streams and potholes, and provide shelter and breeding grounds for wildlife, primarily birds. Because the study areas are located in the Central Flyway--the major bird migration route in North America--and because food in surrounding grain fields is abundant, the incidence of birds and their habitats is high and thus of importance.

The Dahlen and Goose River study areas have considerable topographic relief that would require significant grading (more than two million yd^3 per sector) and would be subsequently susceptible to erosion, with potential impact on rivers. The Galesburg area has intermediate grading requirements; however, the remaining study areas (Blanchard, Thief River Falls, and all of the transmit areas) are flat enough that grading requirements and erosion concerns are minor.

Surface water is extensive at the Dahlen, Goose River, Galesburg, and Wheaton SW study areas, but is present to a lesser extent at Blanchard, Thief River Falls (the western portion), Wheaton N, Wheaton SE, and Amherst. The presence of surface water is likely to require the rerouting of permanent and seasonal drainage features and the filling of potholes and ponds. These actions would disrupt the associated wetlands habitat.

Construction of the groundscreens would cause some agricultural land to revert to natural grasses, thus creating a positive ecological impact.

In addition to wetlands, occasional rows of trees in the areas provide wildlife shelter. With the exception of the eastern half of the Thief River Falls study area, few wooded areas exist. Deer and perhaps moose and elk may use the wooded areas. No federally listed threatened or endangered species are thought to occupy any of the study areas. However, before siting and construction, the selected sites would be surveyed, and appropriate mitigation measures would be taken if required.

Birds may be significantly impacted because of the loss or disruption of habitat and breeding grounds and the possibility of collisions with the antennas. The proximity to wetlands, preserves, the Central Flyway, and grain fields increases the likelihood of collisions. The potential for wildlife impacts is greatest in the Dahlen, Goose River, Galesburg, and Wheaton SW study areas. The eastern portion of the Thief River Falls area contains important wildlife areas, and the western portion contains or borders important wildlife areas; thus, the potential for wildlife impacts exists if the CRS is built near these latter areas. Wildlife impacts at Amherst would depend on the specific location of the site within the study area. The remaining areas, Blanchard, Wheaton N, and Wheaton SE, could satisfy the CRS requirements with minimal wildlife impacts.

The greatest risk to birds is from collision with the backscreen as they fly low between shelter, breeding, and feeding areas. Siting an antenna astride such flight paths should be avoided. Similarly, the risk of collision is greater where water and grain fields are nearby. Higher flying migratory birds would not be affected, except when they use the area for feeding or breeding. The collision risk could be mitigated by increasing the visibility of the structure to avoid creating visual attractions or confusing navigation. Other measures involve means (e.g., sound) to enable the birds to sense the antenna arrays.

Although bird collisions are a potential impact, frequent collisions have not been reported at existing structures in the region that are about as tall as the antenna arrays (e.g., observation towers and silos). Problems with collisions have been reported for much taller towers in the region, however.

The operations center is to be built on existing military grounds at Grand Forks Air Force Base. Therefore, no significant biophysical impacts are likely.

Socioeconomic Effects

Significant adverse socioeconomic effects are not anticipated at any of the nine areas studied as possible antenna array locations or at the proposed operations center location.

Population increases from operations, even in the most sparsely settled study areas, would be less than 1%. During operation, 390 people would be required for the operations center, with 50 each for the transmit and receive sites. CRS operations would reduce local umemployment by about 1 to 3 percentage points, when both indirect effects and the effect of nonlocal hiring are considered. Construction employment would average about 100 workers each at the operations center, transmit, and receive sites over the 3 to 5 years of construction.

The most significant socioeconomic impact would be the removal of land from agricultural use for the transmit and receive sites. However, the net loss of farm income of less than $100 per acre would be more than offset by the total wages paid to the operational personnel at the sites. The tax loss resulting from removal of land and buildings from the tax base would be less than 1% for a county, but would be more significant to individual townships or to those tax districts that include large portions of the selected area. Some landowners would welcome the sale of their property, especially in light of falling real estate values for farm acreage. Others would regard sale of the family farm as a personal loss. From an agricultural resource point of view, the CRS would affect less land than has been removed from production annually in recent years from every county in the study areas except Traverse in Minnesota, where more land has been put into production.

Roads are an important part of the local infrastructure, typically crisscrossing an area in one-mile grids. The transmit and receive sites would require that traffic be rerouted. On the other hand, the roads remaining near the CRS would be improved and maintained.

Because of the generally flat, primarily agricultural land, the natural visual resources in the region are homogeneous. Man-made features such as transmission towers and farm buildings already stand out on the local landscape. Therefore, the CRS antenna arrays would not obscure or detract from existing scenery.

Although the regions considered for the CRS have been important to humans since prehistoric times, relatively few archeological sites are known in the study areas--probably because of the lack of systematic investigation. The existence of important former trails and of the shorelines of ancient lakes suggest the likelihood of finding more archeological sites in the region. Of the study areas, Wheaton SW appears to have the highest potential to contain the most archeological sites, and Wheaton N the least. Cultural impacts would be mitigated after the specific sites were selected for the CRS, the significance of identified sites was evaluated, and a mitigation plan was prepared.

Radiofrequency Radiation

Detailed calculations were made to estimate the magnitude and distribution of radiofrequency radiation (RFR) from the CRS, and the resulting values were used to estimate the possible effects of RFR. The validity of the computational methods was confirmed by measurements made at the Experimental Radar System (ERS) in Maine. The exclusion fence around the transmit antenna arrays would be located so that the average power density at ground level outside the fence would be well below the levels designated by the American National Standards Institute (ANSI) 1982 standard for both occupational and general public exposure.

Human Health

Because radiation safety is of paramount importance, an in-depth, critical review of the available literature on the biological effects of RFR was carried out. That review does not include any system-specific information; rather, it addresses the present state of scientific knowledge on the biological effects of RFR in the range from 0 to 300 GHz. The conclusions regarding possible RFR bioeffects of OTH-B were derived from the most pertinent and scientifically significant results.

Epidemiologic studies performed in the United States and other countries have not provided adequate scientific evidence that environmental levels of RFR constitute a hazard to the general population.

Most U.S. experiments with animals that yielded recognizable and repeatable effects of exposure to RFR were performed at incident average power densities of more than about 1 mW/cm^2 (the ANSI standard). Such effects are thermal, in the sense that the RFR energy is absorbed by the organism as widely distributed heat that increases the whole-body temperature, or as internally localized heat that is biologically significant even with functioning natural heat-exchange and thermoregulatory mechanisms operating.

The existence of threshold values of average power density has been experimentally demonstrated for some effects and postulated for others. Exposure to RFR at average power densities exceeding the threshold for a specific effect for durations of a few minutes to a few hours (depending on the value) may or may not cause irreversible tissue alterations. The

heat produced by indefinitely long or chronic exposures at power densities well below the threshold is not accumulated because its rate of production is readily compensated for by heat-exchange processes or thermoregulation.

Most investigations involving chronic exposures of mammals indicated either that no effects occurred or that reversible, noncumulative behavioral or physiological effects took place for average power densities exceeding 1 mW/cm^2. In the few cases in which irreversible adverse effects of exposure were found, such effects were absent for average power densities below 1 mW/cm^2. In a relatively small number of investigations, biological effects of RFR were reported at incident average power densities of less than about 1 mW/cm^2.

In sum, the review of the relevant literature indicates that no reliable scientific evidence exists to suggest that chronic exposure to RFR from the OTH-B radar outside the exclusion fence would be deleterious to the health of even the most susceptible members of the population such as the unborn, infirm, or aged.

Electromagnetic Interference and Hazard Effects

The CRS would operate from 5 to 28 MHz, which is within what is commonly called the high-frequency (HF) band. Users of HF band communicate between points as far away from each other as the opposite sides of the earth. The band as a whole is shared by other OTH-B radars, air-to-ground and ship-to-shore communications, standard time and frequency broadcasts, the Amateur Radio Service, Citizens' Band radio, and others. The specific portions of the HF band within which the CRS would transmit are also occupied by the Fixed Service (set aside for point-to-point communication between non-mobile stations) and the Broadcast Service (international radio broadcasting stations such as the Voice of America).

The radar can operate on a large number of channels. Its frequency use cannot be predicted exactly, however, because it will depend not only on changing ionospheric conditions, but on the frequencies independently used by other occupants of these bands--frequencies that the radar would attempt to avoid. If the radar were operated on a frequency already occupied, it could interfere with reception at distant receivers. Operation of the ERS for approximately 1 year, however, resulted in no valid reports of interference from either Fixed-Service stations or from listeners on the international broadcast bands.

The radar's modulation has been carefully designed so as not to interfere with reception in the adjacent bands. Occupants of these adjacent bands include the Amateur Radio Service, the Maritime Mobile and Aeronautical Mobile Services, standard time and frequency services, and, when the radar is in the Fixed Service bands, the Broadcast Service. The radar would be operated sufficiently far from the band edges so as not to produce adjacent-channel interference.

The radar would also radiate low-power harmonics of its fundamental frequencies that could interfere with systems using those frequencies. The harmonics would typically not propagate by sky wave to distant regions; thus, any interference effects would be strictly local. Harmonic interference would result from transmission only on particular frequencies. Among the systems considered for potential interference from the radar's harmonics were television, land-mobile radio, air-to-ground radio, and very high frequency (VHF) omnirange (VOR) air navigation beacons.

Information regarding television reception near the transmit study areas or regarding placement of the OTH-B radar within any study area is as yet insufficient to attempt to predict where or when television interference might be produced. Measurements in Maine near the ERS showed that at distances of 6 miles or more from the radar, the radar's harmonics that could potentially interfere with television were were generally so weak that they were not detectable above the background radio noise.

Measurements and experience at the ERS suggested that harmonic interference with low-band VHF land mobile radio was unlikely at distances greater than about 3 or 4 miles, and a similar prediction applies for the CRS.

Although the VHF air-mobile communication frequencies may be susceptible to harmonic interference, no complaints were voiced during the more than a year that the ERS was operated.

Seven VOR and VORTAC ground stations are within about 100 miles of the transmit study areas; aircraft using them would sometimes be illuminated by the OTH-B, and their VOR receivers are potentially susceptible to harmonic interference. Measurements at the ERS indicate that the interference may become severe when the aircraft are within about 30 miles of the front of the transmit array. However, those harmonic interference problems result from operation of the radar only on certain frequencies, which can be determined. The Air Force would cooperate with the Federal Aviation Administration (FAA) to determine whether interference exists and to resolve any interference problems.

At least seven small airports within approximately 100 miles of the transmit study areas are served by nondirectional radio beacons. Aircraft use directional antennas to receive the beacon signals and to determine the direction to the beacon. No experimental information is available to judge whether the OTH-B signal would interfere with aircraft reception of a beacon signal.

Operation of the OTH-B radar is not expected to interfere with reception of broadcast radio beyond about 1 to 2 miles from the transmit site.

The Air Force has developed an "Operational Plan for RF Interference Avoidance" for the OTH-B radars. This plan contains detailed operational procedures to be followed when changing frequencies to avoid producing interference to other users of the radio spectrum. It also contains procedures for cooperative remedial action that the radar operators are to follow when receiving a complaint that the radar has produced interference or is currently doing so.

The OTH-B radar would not be a threat to fuel-handling operations, nor would it constitute a threat to cardiac pacemaker owners outside the exclusion fence.

Some electroexplosive devices (EEDs), such as electrical blasting caps, could be detonated by electromagnetic energy. Safe separation distances depend on the electrical conductivity of the ground. They cannot be determined with certainty until measurements of this parameter are made. Estimates indicate that the storage or transport of EEDs would be safe outside the exclusion fence if they were enclosed in metal containers. Otherwise, the safe distance would be about 2.3 miles in front of the transmitter and about 1,300 feet behind it (depending on ground conductivity). The use or handling of blasting caps in preparation for blasting operations would be safe if it were done at least 4 miles from the front of the transmit array, depending on ground conductivity.

Alternatives Considered

No Action or Postponement of Action

Under this alternative, the CRS would not be constructed and operated on any combination of the study areas, or it would be postponed to allow resolution of specific problems or issues related to these activities. Because the mission requirement would not be satisfied, the Air Force would continue to study the need for and methods to achieve the mission.

Other Surveillance Systems

Under this alternative, airborne or satellite surveillance systems would be used in place of the CRS. However, airborne systems are prohibitively expensive, and satellite systems require additional development.

Other Locations

No alternative locations to those identified as study areas have been considered. Operational requirements defined an optimal siting region. Additional operational criteria identified the EIS study areas and excluded the remaining portions of the siting region.

Conclusion

Significant long-term biophysical impacts from CRS construction and operation are possible, but their occurrence depends on the sites selected. Carefully planned and executed mitigation measures would reduce the likelihood and severity of potential problems. Selection of less environmentally favorable sites would result in some significant short-term impacts and require stronger mitigation measures. No significant adverse socioeconomic impacts would occur.

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GLOSSARY

Abbreviations and Units of Measure

A	Ampere
AAMI	Association for the Advancement of Medical Instrumentation
AASHTO	American Society of State Highway and Transportation Officials
A,B,C,D,E,F	Designations of the six frequency bands of an OTH-B radar, beginning with the lowest frequency
AC	Alternating current (generally refers to the 60-Hz electrical power)
ac-ft/yr	Acre-feet per year
ACGIH	American Conference of Governmental Industrial Hygienists
AFB	Air Force Base
AFR	Air Force Regulation
AFSC	Air Force Systems Command
AFOSH	Air Force Occupational Safety and Health
AM	Amplitude modulation (form of radio signal in which the signal intensity is altered or modulated to encode the sound or data).
AN/FPS-118	Specific model number used by military to designate current OTH-B radar system.
ANSI	American National Standards Institute
API	American Petroleum Institute
AWACS	Airborne Warning and Control Systems

BBB	Blood-brain barrier
BBC	British Broadcasting Corporation
B.P.	Before present
Btu	British thermal units
C	Celsius, temperature scale where freezing water is 0°C and boiling water is 100°C.
cal	Calorie
CB	Citizens' band (radio)
CCIR	Consultative Committee for International Radio
CEQ	Council on Environmental Quality
cfs	Cubic feet per second
cm	Centimeters
CNS	Central nervous system
CO	Carbon monoxide
CRS	Central Radar System
CW	Continuous wave
dB	Decibel; ten times the logarithm of a power ratio; a measure of signal strength compared to an absolute reference.
dBi	Decibels relative to an isotropic source, one radiating in all directions.
dBW	Decibels relative to 1 watt
DC	Direct current
DME	Distance-measuring equipment
DMSO	Dimethyl sulfoxide
E^2	Electric field amplitude
EED	Electroexplosive device

EEG	Electroencephalogram
EIRP	Effective isotropic radiated power, power radiated in all directions.
EIS	Environmental Impact Statement
ELF	Extremely Low Frequency
EMF	Electromagnetic fields
EMI	Electromagnetic interference
EMR	Electromagnetic radiation
EPA	Environmental Protection Agency
ERS	Experimental Radar System; the precursor to the East Coast Radar System in Maine.
eV	Electron volt; a unit of energy
f	Frequency
F	Fahrenheit, conventional temperature scale
FAA	Federal Aviation Agency
FCC	Federal Communications Commission
FDA	Food and Drug Administration
FM	Frequency modulation; a way of modulating a radio signal
ft	feet
FWCA	Fish and Wildlife Coordination Act
g	Gram
GHz	Gigahertz; one gigahertz = 1,000,000,000 cycles per second
gpd	Gallons per day
gpm	Gallons per minute
H^2	Magnetic field amplitude

HEW	U.S. Department of Health, Education, and Welfare
HF	High frequency (band); specifically, 3 to 30 MHz
hr	Hour
HUD	U.S. Department of Housing and Urban Development
Hz	Hertz: one Hertz = 1 cycle per second
in	Inches
IRAC	Interdepartment Radio Advisory Committee
IRPA	International Radiation Protection Association
kg	Kilogram
kHz	Kilohertz; one kilohertz = 1,000 cycles per second
kW	Kilowatt; one thousand watts
m	Meter
MAC	Maximum allowable concentration
MARS	Military Affiliate Radio System
MDNR	Minnesota Department of Natural Resources
mg/l	Milligrams per liter
$\mu g/m^3$	Micrograms per cubic meter; a measure of concentration
MHz	Megahertz; one megahertz = 1,000,000 cycles per second
MITRE	The MITRE Corporation; an Air Force contractor
min	Minute
mm	Millimeter
M.S.	Minnesota Statutes
MSL	Mean sea level
mW	Milliwatt; one thousandth of a watt
MW	Megawatt; one million watts

mW/cm^2	Power density in milliwatts per square centimeter
mV	Millivolt; one thousandth of a volt
NDB	Non-directional beacon
NDGFD	North Dakota Game and Fish Department
NEPA	National Environmental Policy Act
NIEMR	Nonionizing electromagnetic radiation
NIOSH	National Institute for Occupational Safety and Health
nm	Nautical mile; 1 nm = 1.15 mi
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NOTAM	Notice to Airmen
NTIA	National Telecommunications and Information Administration
OTH-B	Over-the-Horizon Backscatter (radar)
OTP	Office of Telecommunications Policy
PAVE PAWS	An Air Force microwave radar system
PEL	Permissible exposure limit
pH	A measure of acidity; pH 7 is neutral
PHS	Public Health Service
P.O.	Post Office
POL	Petroleum, Oil, and Lubricants
pps	Pulses per second
PRF	Pulse repetition frequency
R	Range, a subdivision in the east-west direction used on USGS maps (also see township)

$1/R^2;1/R^4$	One divided by the square or fourth power of the distance; a measure of how much the power density decreases with distance. That is, at a distance of 5 units, the power would be 1/25; at 10 units it would be 1/100.
RCRA	Resource Conservation and Recovery Act
RF	Radiofrequency
RFEM	Radiofrequency electromagnetic (fields)
RFR	Radiofrequency radiation
s	Seconds
SAR	Specific absorption rate
SHSND	State Historical Society of North Dakota
SITS	Smithsonian Institution Trinomial System, a method for numbering cultural sites
S/m	Siemens per meter (unit of conductivity)
SO_2	Sulfur dioxide
SPCCP	Spill Prevention Control and Countermeasure Plan
SWBC	Short-wave broadcast bands
T	Township, a subdivision of land in the north-south direction used on USGS maps (also see range).
TACAN	Tactical Air Navigation System
TLV	Threshold limit value
tpy	Tons per year
TSP	Total suspended particulates
TV	Television
UHF	Ultra High Frequency (band); specifically 300 MHz to 3 GHz. Includes TV channels above Channel 13.
USAF	U.S. Air Force

USAFSAM	U.S. Air Force School of Aerospace Medicine
USC	U.S. Code
USDOI	U.S. Department of the Interior
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
V	Volt
VHF	Very high frequency (band); specifically 30 to 300 MHz. The VHF band includes TV channels 2-13.
V/m	Volts per meter; electric field strength
VOR	VHF omnirange beacon
VORTAC	A VHF omnirange beacon colocated with a Tactical Air Navigation System
W	Watts
WHO	World Health Organization
w/kg	Watts per kilogram
WMA	Wildlife Management Area
WPA	Waterfowl Production Area
WRF	Waveform repetition frequency
yr	Year

Definitions

Aeromagnetic	A survey of the earth's magnetic field made with an airborne magnetometer
Amphibole schists	A layered rock which splits or flakes, containing hornblende
Amphibolite	A type of metamorphic rock
Aperture	An opening through which energy enters or exits

Aquifer	A saturated permeable geologic unit that can hold significant quantities of water
Archeological	Relating to the study of material remains (fossil relics, artifacts, monuments) of past human life and activities
Artesian	A type of well or underground basin, where the water is under pressure and will rise to a higher elevation if allowed to do so
Atria	Main chamber of an auricle of the heart
Azimuth	Horizontal measure of angular direction
Bentonite	A clay mineral
Blacksoil prairie	The original, natural condition of the Red River Valley, before conversion to agriculture
Blood-brain barrier	A sack which separates the fluids in the brain from the rest of the human body
Boresight	The specific direction in which an OTH-B antenna array is pointed or aimed
Borrow	Gravel material, usually unprocessed, that is used as fill material for construction earthwork
Bradycardia	Relatively slow heart action
Browse	To feed on the tender shoots, twigs, and leaves of trees and shrubs
Calorimetry	Measurement of heat production
Cardiac pacemaker	An electric device that artificially stimulates the heart to beat
Cataractogeneous	Causing of cataracts in the eye
Cellular suspensions	A well-mixed liquid containing small biological particles or cells

Central Flyway	One of four main arteries for wildfowl migrating through North America. The route extends from the northern spring breeding grounds (which occur from Nebraska all the way to Siberia) to the southern wintering grounds (which are found from Texas south to Mexico)
Circadian rhythm	The daily biological cycle of about 24 hours; biorhythm
Coliform bacteria	An organism whose presence in a water sample means that the water is contaminated by animal wastes
Community	Group of populations of plants and animals in a given place
Conductivity, ground	Measure of how easily electricity can pass through the earth; depends on water and amount of salts
Coniferous	Cone-bearing, needle-leaved evergreens
Contractile	Having the power or property to contract
Cretaceous	The final period of the Mesozoic Era, 136 to 65 million years ago
Culvert	A pipe which channels water runoff
Dabbling ducks	Ducks that nest on land and inhabit shallow peripheral areas of water bodies
Deeryard	A place where deer herd in winter
Deciduous	Referring to trees and shrubs that lose their leaves in the fall
Diathermy	Production of heat in tissue by radiofrequency for medical treatment
Dielectric constant	Property of a material, which is not electrically conducting, to be affected by electric fields
Dipole	An antenna with equal rods or elements in opposite directions

Diving ducks	Ducks that nest over water and spend the greater part of their time on relatively deep open water areas
Ecotone	Transition zone between two diverse communities (e.g., the prairie - deciduous forest ecotone)
Electric vector	The direction of an electric field force
Electroexplosive device	A device such as a blasting cap for detonating explosives
Electromagnetic	Combined effects having to do with electric and magnetic fields
Electromagnetic radiation	Energy emitted as particles or waves
Emergent vegetation	Vegetation that may be temporarily to permanently flooded at the base but does not tolerate prolonged inundation of the entire plant
Endangered (species)	Threatened with extinction
Endocrine	Hormone-secreting
Endocrinology	Study of endocrine glands and their secretions; science of hormones
Ephemeral ponds	Ponds which last only a short time
Epidemiology	Study of factors, such as disease, affecting large numbers of persons
Escarpment	A long more or less continuous cliff or steep slope facing in one general direction
Eutrophication	A process by which water becomes rich in dissolved nutrients and depleted in dissolved oxygen; typical in a small lake with strong growths of plants such as algae
Far-field	The electromagnetic field distant from the energy source
Floodplain	An area that over many years may be flooded at one time or another
Flyway	The route of bird migrations

Forage	To search for food
Forbs	Non-grassy herbs such as composites and legumes
Galactic noise	Radiofrequency radiation coming from the sun and stars that may be detected by radio receivers; extraterrestrial static
Game Production Area	An area managed by the South Dakota Department of Game, Fish and Parks for the production of waterfowl or other game species
Glacial drift	Material which has been deposited by a glacier or in connection with glacial processes. It consists of rock flour, sand, pebbles, cobbles and boulders
Glaciated	To be covered with a glacier
Glaciofluvial deposit	A deposit laid down by a stream originating in a glacier. Such deposits, while consisting of glacial drift, are usually well sorted by the running water, which carries the finer materials a greater distance from the glacier before depositing them
Gneiss	A banded metamorphic rock
Grazer	An animal that feeds on growing grass or other herbaceous vegetation
Groundscreen	A wire mesh, lying on or near the ground, that forms part of the transmitter circuit
Ground wave	An electromagnetic field propagated through the ground
Habitat	The place normally occupied by a particular organism or population
Handy-talky	Walkie-talkie
Hardness	Metallic ions in water which produce films and residues
Herbaceous	A plant with no persistent woody stem above the ground; green and leaflike

Histopathology	Study of diseased or damaged tissue
Holocene	Geologic epoch which began 10,000 years ago
Hydrocarbon	A chemical compound consisting solely of carbon and hydrogen
Hydrology	A science dealing with the properties, distribution, and circulation of water on the surface or in the soil and underlying rocks
Hypothalamus gland	Part of the brain which secretes hormones and refulates temperature and metabolism
Impoundment	A pond, lake, tank, or basin, that is used for storage, regulation, and control of water
Infiltration	The flow or movement of water through the interstices or pores of soil or other porous medium
In-vivo	A biochemical process carried out in a living system as opposed to being carried out in a test tube
Ionizing radiation	Energy emissions, such as ultraviolet light, x-rays, and emissions from radioactive materials that can cause chemical species to break down into ions
Ionosphere	Region of the earth's atmosphere, beginning at an altitude of about 30 miles and extending 250 miles or more above the surface, where the air molecules exist in layers of ions of charged atoms or molecules
Kaolinite	A common white to grayish clay mineral of the kaolin group
Lacustrine	Related to or growing in lakes
Lagoon	A pond, containing raw or partially treated wastewater, in which stabilization occurs

Landfill	A system of trash and garbage disposal in which the waste is buried between layers of earth
Lenticular	Having the shape of a double-convex lens
Lignite	Coal with woody texture
Linearly polarized plane	Wave field (the "E" orientation); a field of emitted radiation in which the radiofrequency waves are aligned or polarized in a plane
Loamy	A soil type consisting of clay, silt, and sand
Lobe	An electromagnetic beam
Lossy	Causing attenuation or dissipation of electrical energy
Macromolecule	A large molecule composed of many atoms; a polymer, e.g., a protein
Macrophyte	Plant life forms which are macroscopic, that is, not microscopic
Main lobe	The main beam of the antenna
Mesozoic	An era of geologic time approximately 600 to 65 million years ago
Microwave hearing	A sharp radio pulse that may interact with the body so as to be heard
Milk vetch	A type of climbing plant
Mineralized	Saturated or filled with minerals or inorganic compounds
Moraine	A mound or ridge deposited by the action of glaciers
Moulting	The process of a bird shedding feathers
Mound	Mound of earth covering an aboriginal grave
Mutagenesis	The causing of mutations or alteration of genetic characteristics

Neonatal	Newly born
Neurasthenic	Relating to an emotional and psychic disorder characterized by impaired functioning in interpersonal relationships and often by fatigue, depression, feelings of inadequacy, headaches, hypersensitivity to sensory stimulation, and psychosomatic symptoms (disturbances of digestion and circulation)
Nonthermal	Not caused by, or not causing heat
Omnivorous	Consuming both animal and plant foods
Ordovician	The second earliest period of the Paleozoic Era, 500 to 430 million years ago
Outwash	Drift carried by running water from a glacier and deposited beyond the marginal moraine
Paleozoic	The geologic period between 220 and 600 million years ago when fish, reptiles, and insects first appeared
Palustrine	Pertaining to a wetland characterized by the presence of emergent plants rather than open water, although a small amount of open water may be present
Passerines	Perching birds
Penetration depth	The extent to which energy penetrates
Permeability	Property of soil that permits the passage of water
pH	Used to express both acidity and alkalinity on a logarithmic scale whose values run from 0 to 14 with 7 representing neutrality, numbers less than 7 indicate increased acidity, and numbers greater than 7 indicate increased alkalinity
Physiographic	Pertaining to a region, all parts of which are similar in geologic structure and climate

Physiological	Having to do with biological functions
Plasticity	The quality or state of being plastic, especially, the capacity for being molded or altered
Pleistocene	An epoch of the Quaternary Period, one million to ten thousand years ago
Polarized radiation	An emitted energy field in which the waves are aligned
Polypeptides	A polymerized group of amino acids; a small protein
Population	Group of individuals of a single species
Prairie potholes	Small palustrine emergent wetlands where wetland vegetation grows in glacial depressions. They may be temporary, drying up in summer, or permanent
Precambrian	The earliest period of the earth's history ending 600 million years ago, during which time the crust of the earth was formed and the most primitive life forms appeared
Prolate spheroid	Elongated sphere, football shaped
Pulse modulation	A means of changing radiofrequency pulsed signals by systematically varying the characteristics of the signal, such as the pulse width
Quanta	Small quantities or "packets" of energy
Quantum absorption	A situation where energy is absorbed only in discrete "packets" or quanta
Quaternary	Geological time period beginning 2,000,000 years ago and continuing to the present time
Radiofrequency radiation	Emitted energy within a frequency range from several hundred kHz to several hundred GHz

Radionavigation system	A means by which radio signals are used to determine position and direction for navigation
Raptors	Birds that prey on live animals
Recharge zones	Portions of the drainage basin where water flows into the water table
Resonant	A situation where tuned waves of energy reinforce one another
Richter scale	A logarithmic scale for measuring the strength of earthquakes
Riparian	Vegetation associated with a river
Riverine	Relating to, formed by, or resembling a river
Runoff	Water which comes to the earth as rain and flows over the land into lakes, rivers and streams
Saline water	Water containing dissolved salts
Scatter	Cultural material such as fire-cracked rocks, pottery sherds, stone tools, etc.
Schists	A crystalline rock that splits easily into slabs
Sector	The area covered by the antenna array, groundscreen, support building, and excluded area associated with each 60° arc of radar coverage
Seismology	The study of earthquakes and of the structure of the interior of the earth
Semipermanent wetlands	Wetlands that may dry up in the summer
Septic tank	A settling tank in which settled sludge is in immediate contact with the wastewater flowing through the tank and the organic solids are decomposed by bacterial action
Shale	A fine-grained sedimentary rock formed from clay, silt, or mud

Shelter belts	A row of trees that provide shelter against wind
Sinusoid	A smooth, regularly-shaped wave in the form of a sine wave
Sky-wave propagation	Refraction of electromagnetic energy from the ionosphere in a manner which permits the signal to illuminate portions of the earth far beyond the earth's curvature
Sounder	Transmitter and receiver system for measuring ionosphere characteristics of the ionosphere
Species	A fundamental category on group of organisms that are reproductively isolated from all other such groups
Staging area	An area where migrating birds assemble and prepare for migration
Strand line	A former shore line now elevated above the present water level
Subspecies	Geographical unit of a species disting-uishable by certain morphological, behavioral, or physiological characteristics
Symptomatology	Characteristics that exhibit the properties of a disease
Tachycardia	Excessively rapid heart beat
Tectonically	Pertaining to the forces involved in, or the resulting structures or features from earth deformation
Teratogenesis	Causation of abnormalities in fetuses
Thermoregulatory system	Physiological system that maintains a body at a particular temperature whatever its environmental temperature
Threatened (species)	On the verge of becoming endangered
Till	Unstratified glacial drift consisting of clay, sand, gravel, and boulders intermingled

Topography	The configuration of a land surface including its relief and the position of its natural and man-made features
Turbidity	A measure of the clarity of water; depends on the amount of suspended solids or organisms in the water
Waste assimilation	The incorporation of waste into ambient water
Water quality	The chemical, physical, and biological characteristics of water with respect to its suitability for a particular purpose
Waterfowl Production Area	Area owned by the U.S. Fish and Wildlife Service and managed as a nesting area for waterfowl
Wetlands	Areas where the surface soil is water saturated at least part of the year and vegetation characteristic of wet areas is generally present
Wet meadow zone	Temporarily flooded
Wet prairie-sedge	A temporarily flooded wetland dominated by sedges, a common wetland emergent plant
Workability	The relative ease or difficulty in working soil with construction equipment

1 PURPOSE AND NEED FOR ACTION

The Over-the-Horizon Backscatter (OTH-B) radar is a surveillance and tracking radar system that the U.S. Air Force plans to construct and operate in four locations in the United States. The functions of these radar systems are to detect, track, and give early warning of aircraft and cruise missiles approaching North America to the North American Aerospace Defense Command and the National Command Authorities.

Early warning of hostile aircraft approaching North America is critical to the defense of the United States. The OTH-B radar system is able to detect aircraft continuously at any altitude at distances from 500 to 1,800 nautical miles (nm) from the receive site. The range of conventional, microwave radars is limited by the earth's curvature to line-of-sight coverage out to a few hundred miles. This range affords little advance notice of high-speed aircraft flying at low altitudes. The OTH-B system would provide a substantial improvement in warning time.

Collectively, the four OTH-B systems the Air Force plans will establish a surveillance zone surrounding North America, except to the north (see Figure 1-1). The modernized Distant Early Warning (DEW) line--known as the North Warning System--will cover the northern approaches to North America. The subject of this Environmental Impact Statement (EIS), the Central Radar System (CRS), is needed to complete the perimeter coverage of the southern approaches to North America. It also is needed to scan near-shore ocean areas for sea-launched cruise missiles.

Airborne and satellite surveillance systems are possible alternatives to the OTH-B system. However, the airborne systems are not cost-effective, and satellite systems cannot be built until key technical advances are made--advances that are not expected to be achieved in the foreseeable future. Consequently, constructing and operating the four OTH-B radar systems is clearly needed to meet threats to North America posed by aircraft and cruise missiles.

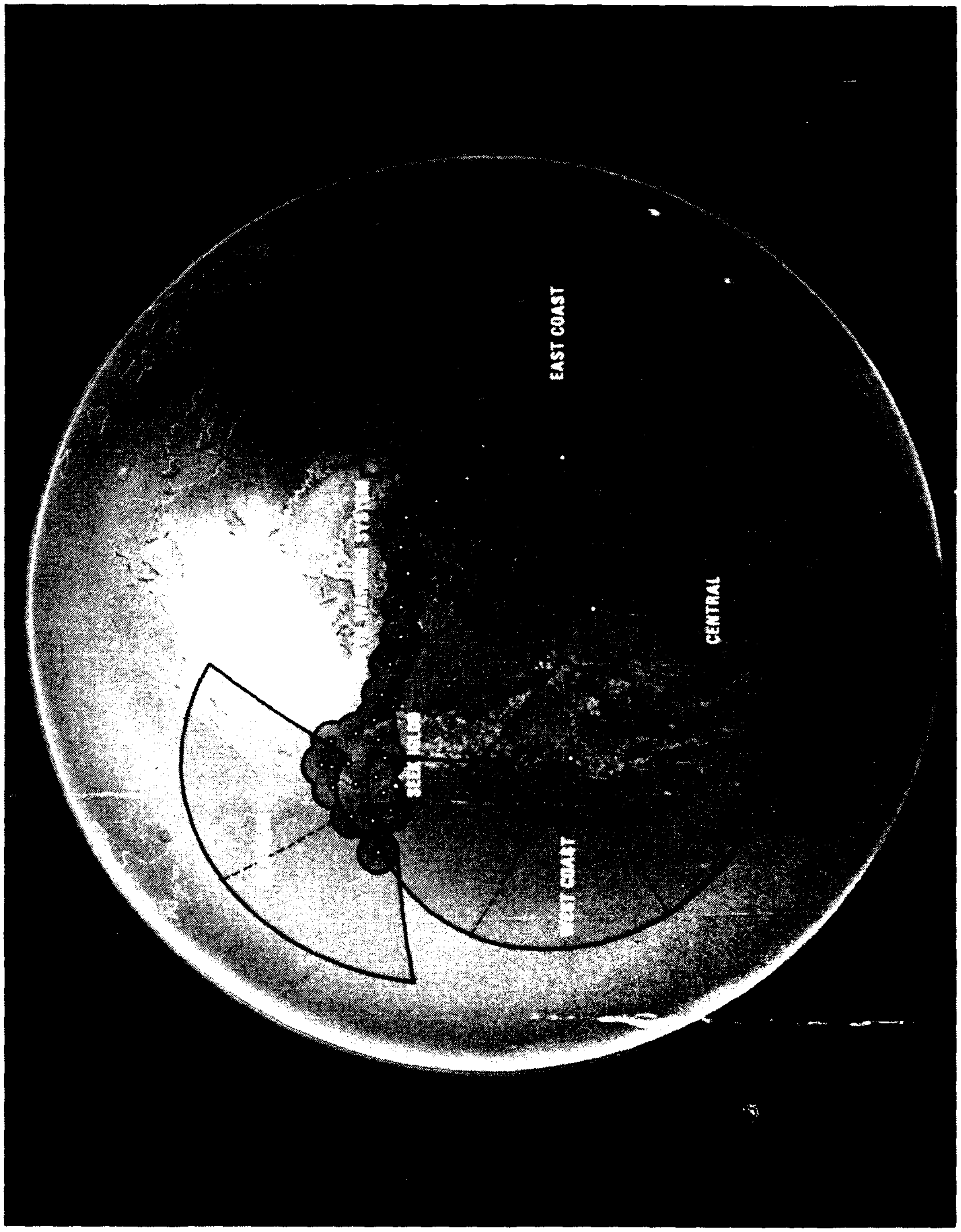

FIGURE 1-1 CONTINENTAL COVERAGE OF OTH-B SYSTEMS

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2 PROPOSED ACTION AND ALTERNATIVES

2.1 Proposed Action

2.1.1 The OTH-B Radar System

2.1.1.1 Background and Concept

The proposed action is the construction and operation of an Over-the-Horizon Backscatter (OTH-B) radar system by the U.S. Air Force in the north central region of the United States. The purposes of the this OTH-B radar, to be known as the Central Radar System (CRS), are to detect, track, and provide early warning of aircraft and cruise missiles approaching from the south or from near-shore areas off the East, West, and Gulf Coasts. This document describes the proposed action, candidate CRS siting areas, and the effects of construction and operation in those areas. Alternative surveillance systems and the alternatives of no action or postponement of action are also discussed.

The proposed system is quite similar to the Experimental Radar System (ERS) that was built and operated in Maine between 1975 and 1981. The ERS has been dismantled, and construction of a production OTH-B system providing 180° of coverage is in its final stages at the same sites. Operation is scheduled for late 1987. Construction of a second OTH-B system on the West Coast began in July 1986. Another OTH-B system is planned for Alaska and is the subject of a separate EIS.

An OTH-B system differs from conventional, microwave radars in several important respects. Rather than being colocated, the principal system components (i.e., transmit site, receive site, and operations center) are separated by many miles. Instead of one antenna, the system uses many antennas, and instead of being compact, it occupies a large amount of land. In contrast with microwave radars, which radiate power in brief pulses separated by long periods of rest, an OTH-B system radiates continuously. Rather than using frequencies within a relatively narrow band, it uses frequencies chosen from a wide band. Finally, instead of following a straight line to and from the target, the electromagnetic waves from an OTH-B system are bent or refracted by the ionosphere to reach locations beyond the horizon.

Figure 2-1 illustrates the operational concept of an OTH-B system. The surveillance zone (or barrier) created by the radar is a partial ring about 500 nautical miles (nm) wide, beginning 500 to 1,300 nm from the receive site. The CRS barrier would span a 240° arc, from an azimuth of about 56° (east-northeast), clockwise, to approximately 296° (west-northwest). The CRS facilities would be located to cover southern

FIGURE 2-1 OPERATIONAL CONCEPT OF OTH-B RADAR SYSTEM

approaches to North America, to overlap the coverage of the East Coast and West Coast Radar Systems, and to cover near-shore ocean areas.

The transmit and receive sites must be separated by 50 to 150 nm from one another to prevent the transmitters from interfering with reception of the signal reflected from the target. The operations center must be located at a nearby military installation where the operating staff can be based, and the receive site should be within 50 nm of the operations center.

2.1.1.2 Transmit Site

The principal features of an OTH-B transmit site are shown in Figure 2-2, which is a photograph of one of the three East Coast Radar System (ECRS) transmit antenna arrays. The antenna array, which is approximately 4,000 ft long, consists of 6 separate sections, called subarrays, which together span the frequency band from 5 to 28 MHz. Each subarray, in turn, consists of 12 radiating elements. The complete antenna system thus is a linear array of 72 radiating elements mounted on vertical steel towers. The array has a backscreen (behind the array) from 35 to 135 ft tall and a groundscreen (wire mesh on level ground in front of the array) extending out 750 ft. A 15,000-ft^2 building to house the transmit equipment is located behind the array. The building is also used by the staff responsible for operations, equipment maintenance, and site security. The CRS staff would total 50 persons; 10 to 12 would work each 8-hour shift. A wooden (or equivalent non-conducting) exclusion fence surrounds the transmit array, groundscreen, and building. A road outside the fence is used for security patrols. The CRS site would be connected by an access road from the nearest county road or highway.

To provide the necessary coverage, the CRS transmit site would have four separate fixed antenna arrays oriented 60° from one another. Each transmit array--paired with an array at the receive site--would cover a partial ring 500 to 1,800 nm in range and 60° in azimuth. The four antenna arrays would face east (85° compass direction), southeast (145°), southwest (205°), and west (265°). A representative layout is shown in Figure 2-3. The actual arrangement of the 4 antenna arrays would depend on terrain and other factors at the selected transmit site, but a minimum of 2,400 acres would be required.

The radar beam produced by each transmit array would be electronically steered in steps of 7.5° (for a total azimuth change of ±30°) by varying the phase (i.e., timing) of the electric current delivered to the radiating elements. Under normal circumstances, the four CRS transmit arrays would radiate simultaneously and cooperatively to maintain the surveillance zone. The wavelengths of the OTH-B radar beam vary from 10.7 to 60 meters (m). These wavelengths are similar to those radiated by radio amateurs and "short wave" radio stations, but are much longer than those of conventional radars, which have wavelengths from a few centimeters (cm) to about 1 m. Only one subarray of each antenna system would be driven at any one time, and the frequencies radiated

FIGURE 2-2 EAST COAST RADAR SYSTEM TRANSMIT SITE

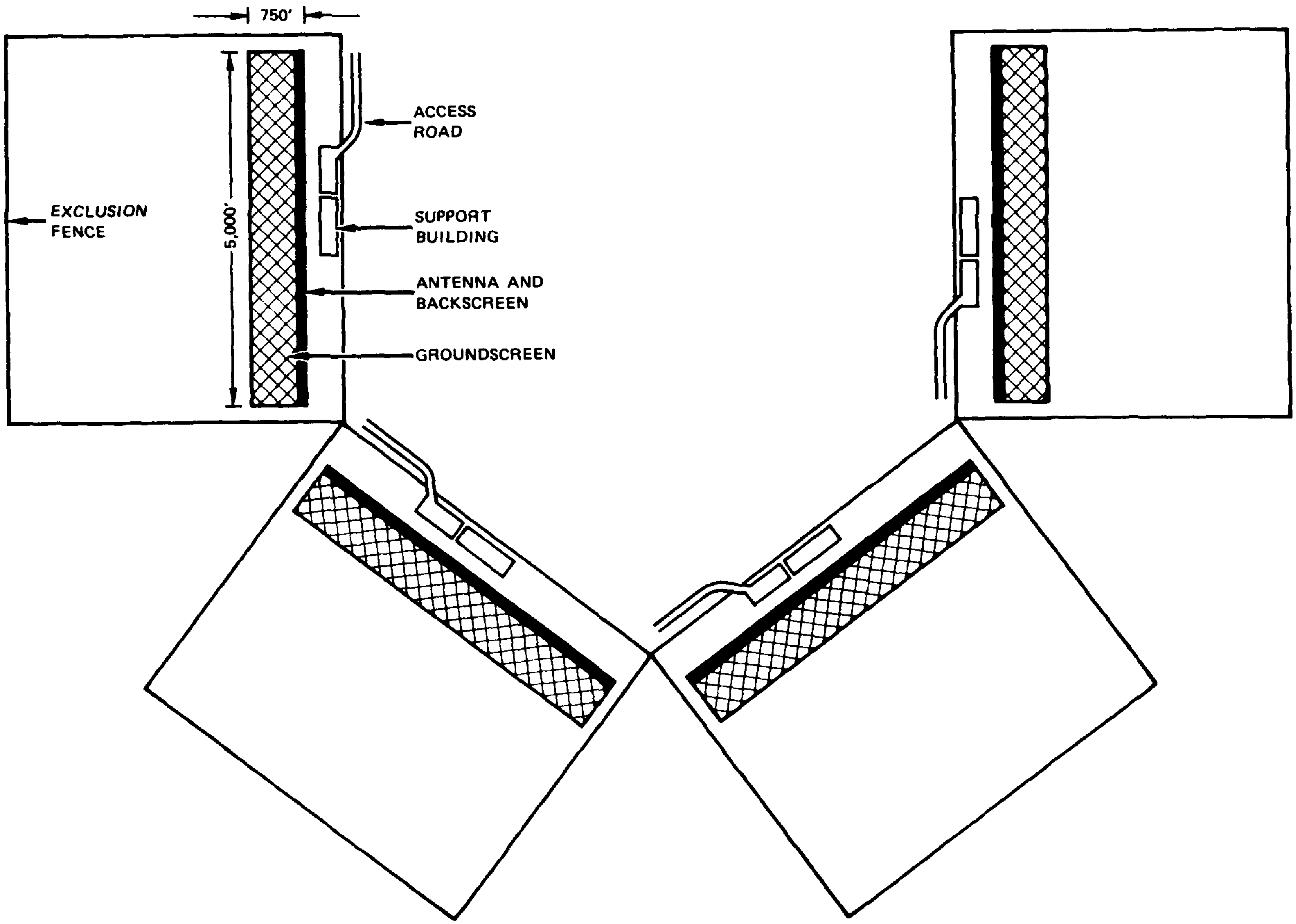


FIGURE 2-3 SCHEMATIC OF REPRESENTATIVE CRS TRANSMIT SITE

from each of the four CRS arrays would usually differ from one another. Further details of the transmit system are contained in Appendix A. The beam would point in a particular direction for a brief interval, which may be as large as 10 seconds. Because 8 steps of 7.5° would be required to cover 60°, as many as 80 seconds could pass before the beam returned to a given direction.

Because only the transmit arrays would radiate electromagnetic energy, there is particular interest in the transmit site and the nature and magnitude of the resulting radiofrequency radiation (RFR). RFR from a transmit array forms a concentrated beam that moves outward and upward from the site. The effective width of the beam is about 8.4°, the effective height about 24°, and the upward or takeoff angle in the range 1° to 25°. When the beam reaches a height of about 50 to 150 miles, it enters a region of the atmosphere called the ionosphere and is refracted (bent) back toward the earth. On reaching the earth, the energy of the incident beam is reflected and scattered again. A small fraction of the reflected beam returns toward the source, again to be refracted by the ionosphere, and reaches one of the receive arrays. Signal processing equipment analyzes the return beam to detect aircraft and cruise missiles.

Most of the power delivered to each transmit array would appear in the main beam and leave the transmit site. However, some energy would be dissipated in other, less powerful beams. These other beams are called backlobes if their general direction is opposite to that of the main beam, or sidelobes if their general direction is the same as that of the main beam. The RFR intensity of the backlobes would be less than one-tenth that of the main beam.

2.1.1.3 Receive Site

The receive site plan would be similar to that of the transmit site. The principal differences would be a longer antenna array (about 9,000 ft), a closer exclusion fence, and the use of only a single subarray with a uniform 65-ft tall backscreen. The exclusion fence would enclose the groundscreen and adjacent support building for security; RFR hazards are not a concern. A plot of land roughly 10,000 ft by 2,600 ft (about 600 acres) would be required for each receive array and exclusion area; thus, the receive site would require a total of at least 2,400 acres. The adjacent buildings would be somewhat smaller than those for the transmit site (5,000 ft^2) because receiving equipment is smaller than high-power transmitters. One building would be used by the staff of approximately 50 (10-12 per shift) to operate and maintain equipment and to provide security. Figure 2-4 is a photograph of one of the ECRS receive arrays.

2.1.1.4 Operations Center

The operations center would be a nontransmitting, 48,000-ft^2 building for equipment and a staff of about 390 contractor and Air Force personnel. It would control the operation of the transmit and receive

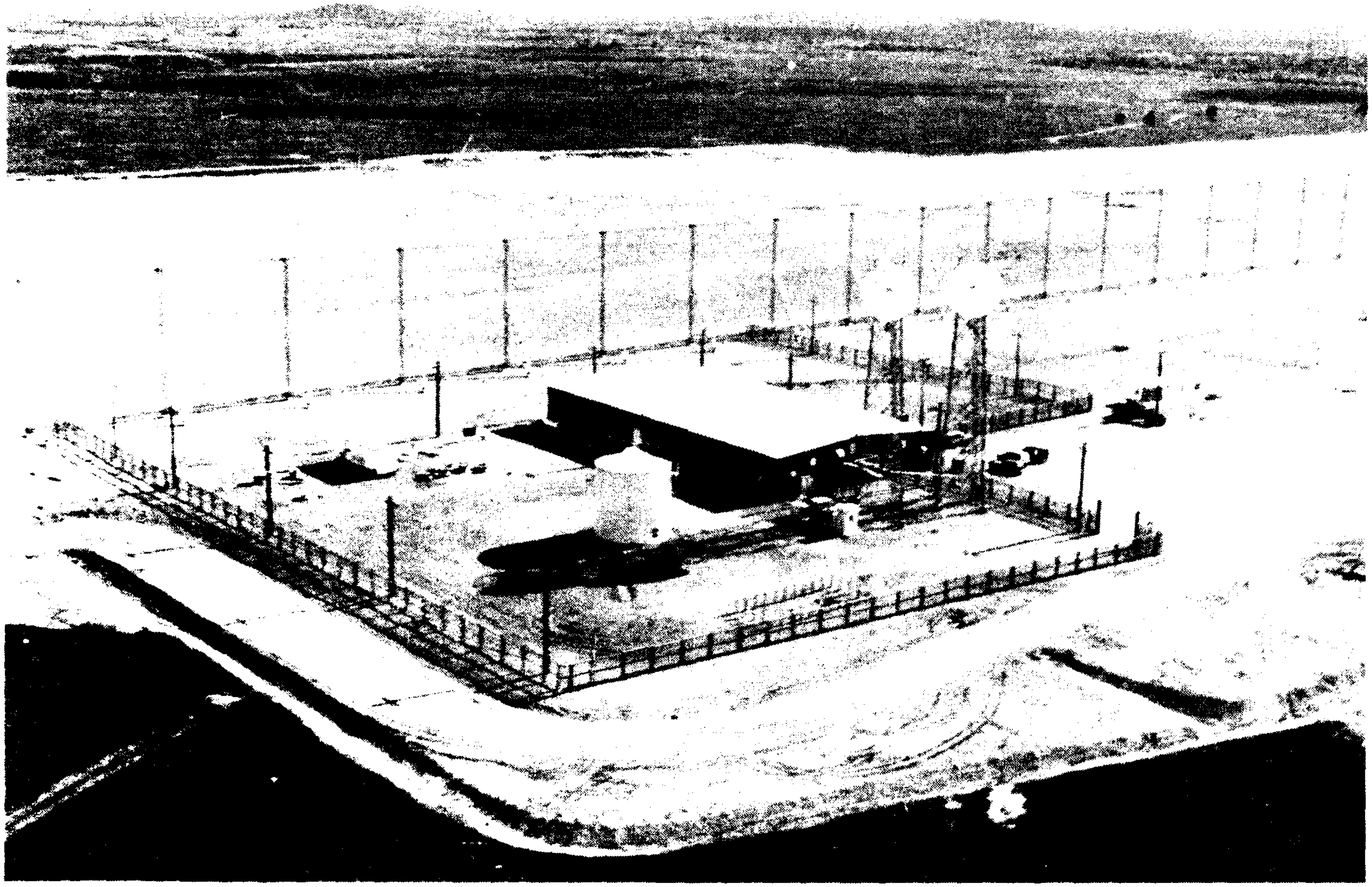


FIGURE 2-4 EAST COAST RADAR SYSTEM RECEIVE SITE

arrays. Using data from the transmit and receive sites, the operations center would detect, track, identify, and report all aircraft and cruise missiles within the coverage area.

2.1.1.5 Communications

Communication systems for the CRS would include telephone lines for administrative and routine operating matters; a classified telephone system; and both classified and unclassified data handling systems. The capacity and design of the communication systems would not be determined until the design for the entire CRS system was under way.

Commercial telephone lines and switching networks would be used for routine telephone calls. New telephone lines would be needed only from the transmit and receive sites; the operations center would be located in an area where service is currently provided by commercial telephone companies. A tropospheric scatter radio link would transmit data from the receive systems to the operations center for processing.

2.1.1.6 Power

The transmit site would require 16 MW of electrical power, and the receive site would require 1 MW. The Air Force intends to buy power from commercial sources near the selected sites. If two highly reliable and independent sources of power were available, the Air Force would not build standby power plants. If the necessary reliability could not be obtained in this way, the Air Force would construct a standby power plant at each site with sufficient capacity (1 MW) to meet all requirements except those for transmitting.

2.1.1.7 Schedule

Construction of the CRS is scheduled to begin in 1988 and continue for as many as five years until all four transmit-receive array pairs have been completed. Operation would begin in the early 1990s.

2.1.1.8 Land Acquisition

To construct the CRS, the Air Force must acquire title to or use rights for the necessary land. Normally, the Air Force would purchase the land. However, many people in the study areas have expressed considerable interest in having the Air Force lease the land so that title to the land would remain in the hands of current families. The Air Force is willing to consider leasing the land it needs, provided that the cost to lease would be reasonably related to the cost of purchase, and that other lease terms would be adequate for the project's needs. Whether the land were purchased in fee or leased, the Air Force would offer fair market value as established by independent appraisals, and negotiations would be conducted with each landowner.

2.1.1.9 Decommissioning

Current plans call for the CRS to operate continuously for at least 20 years after normal operations begin. Decommissioning would be accomplished in accordance with the applicable laws and regulations at that time. If the land was purchased, it would be made available for other federal use. If the land was leased, it would be disposed of in accordance with the terms of the lease.

Improvements to real property would be left in place or removed, according to the circumstances and the terms of any lease agreement. Any demolition would be carried out in compliance with applicable federal, state, and local regulations. The sites would be examined under the Department of Defense Installation Restoration Program before disposition to ensure that no contamination problems existed.

2.1.2 Location of the Proposed Action

2.1.2.1 Site Selection Process

The general location of the CRS was identified by systematic application of various criteria. The first requirement for acceptable site locations was that the necessary radar coverage could be provided from the identified sites. The following operational criteria were used in specifying the required coverage:

- Supplement East Coast and West Coast Radar System coverage to cover near-ocean areas and to overlap the coasts (see Figure 1-1).
- Overlap the North Warning System in the Northeast
- Complete the arc of contiguous OTH-B coverage across the southern approaches to North America
- Meet the preceding coverage requirements from one transmit site and one receive site.

Given the minimum and maximum ranges of the OTH-B system, application of these criteria defined the search area outlined in Figure 2-5. This search area is bounded approximately on the north by 49° north latitude, on the south by 44.2° north latitude, on the east by 94° west longitude, and on the west by 98° west longitude.

With a search area defined by radar coverage requirements, the next step was to identify areas that met site selection criteria related to specific features or off-site influences. These criteria include:

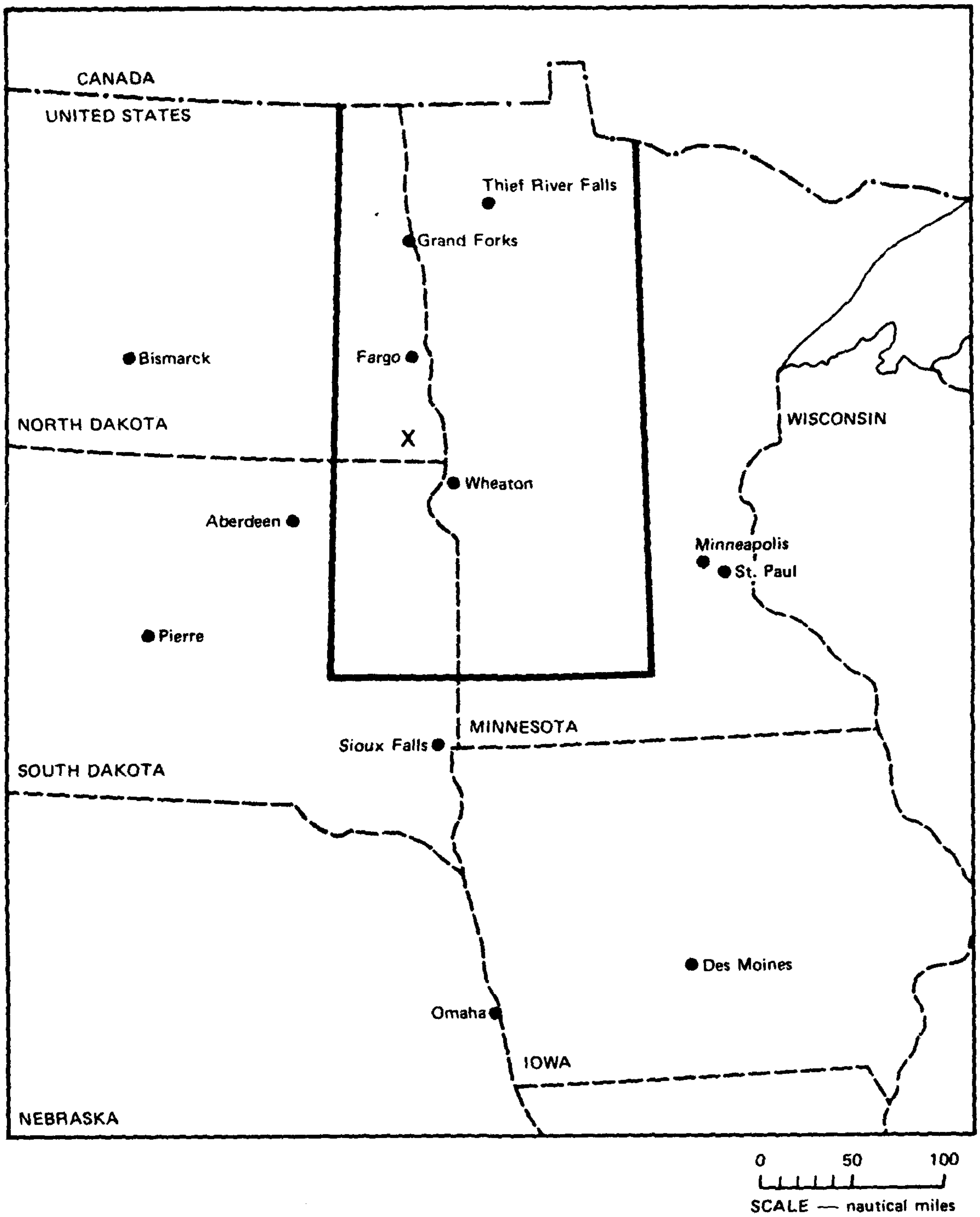


FIGURE 2-5 SITE SEARCH AREA FOR THE CENTRAL RADAR SYSTEM

- Sufficient land to accommodate four antenna arrays

- No obstructions rising more than 1° above the horizon within the azimuth to be scanned

- Flat terrain, or terrain that slopes downward from the arrays in the scan directions

- More than 5 miles from high voltage transmission lines

- More than 5 miles from population centers of 1,000 or more that would be behind the antennas, and more than 10 miles from centers that would be in front

- More than 10 miles from airways.

The set of areas that met these criteria was reduced by application of OTH-B system operational considerations. First, technical analyses showed that the receive site should be located within about 125 nm of the optimal receive site location, which is in the southeastern corner of North Dakota near 46° north latitude and 97° west longitude. Therefore, receive areas not within 125 nm of the optimum location were eliminated.

To limit communication system and logistics support costs, the receive site should be within about 50 nm of the operations center. Furthermore, the operations center should be located at an existing Air Force installation to minimize support costs. When these two requirements were applied, Grand Forks Air Force Base was identified as the only military installation acceptable for the operations center.

Finally, the transmit site should be located no more than about 150 nm from the receive site and a similar distance from the operations center.

Application of all requirements led to identification of the nine study areas shown in Figure 2-6. The 5 areas in North Dakota and 1 in northern Minnesota are suitable for receive sites; the 3 areas in southern Minnesota and the 1 in South Dakota are suitable for transmit sites.

2.1.2.2 Study Areas

A study area is a unit of varying size that meets the OTH-B siting criteria. This EIS discusses 9 study areas for the transmit and receive sites and one proposed site for the operations center. The EIS does not examine specific sites within the study areas.

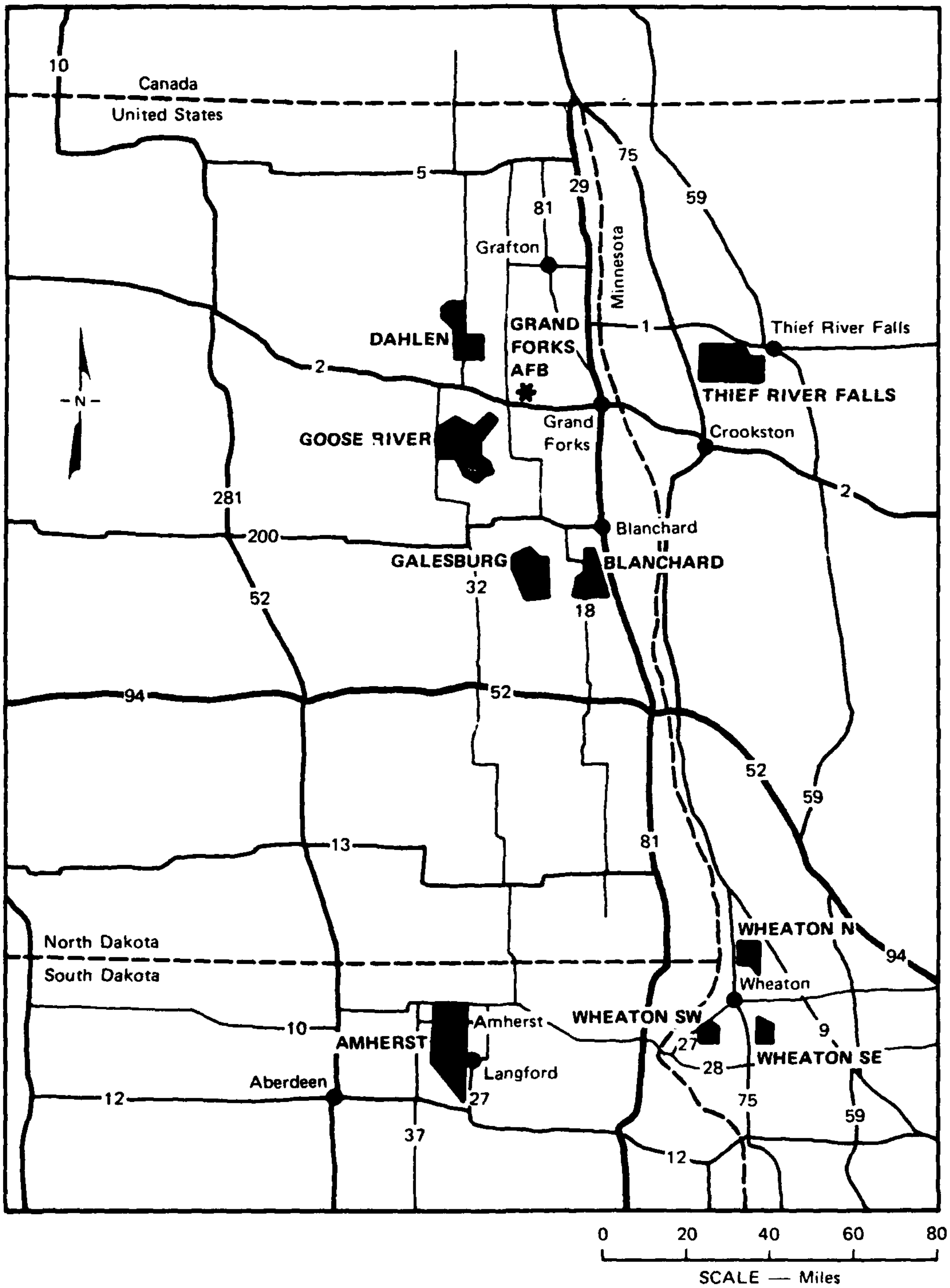


FIGURE 2-6 CENTRAL RADAR SYSTEM STUDY AREAS

A study region is a group of one to three adjacent, but not contiguous study areas that for the purpose of analyzing certain aspects of the environment possess essentially the same characteristics.

The study regions, study areas, and associated CRS functions are listed in Table 2-1. Maps of the individual study areas are presented in Figures 2-7 through 2-15. The table and maps show precise study area boundaries, but because most features of the environmental setting do not conform to these precise descriptions, the analysis of impacts was not restricted to these arbitrary boundaries.

A site is the specific location within a study area where the CRS facilities would be located. A specific site has not yet been selected for the transmit and receive antenna arrays pending the results of various environmental, operational, engineering, cost, and land availability studies that would influence the selection of a study area and a site within the study area.

2.1.2.2.1 North Dakota-North Region

The North Dakota-N region is located in western Grand Forks, eastern Nelson, southern Walsh, and northwestern Steele counties about 30 miles west of Grand Forks. U.S. Highway 2 bisects this region into the Dahlen and Goose River study areas. The region is exclusively rural and devoted to agriculture. The towns of Fordville, Inkster, Orr, Dahlen, McCanna, Larimore, and Aneta lie within this region.

The Dahlen study area is located at the juncture of Walsh, Grand Forks, and Nelson counties, and consists of 87 contiguous sections or portions of sections. Both the Middle and South branches of the Forest River traverse the study area.

The Goose River study area is located west of Northwood, in extreme southwestern Grand Forks County and in adjacent Nelson and Steele counties. Approximately 125 contiguous sections or portions of sections of gently rolling landscape are included.

2.1.2.2.2 North Dakota-South Region

The North Dakota-S region is in southwestern Traill, southeastern Steele, and northern Cass counties, southwest of the town of Hillsboro. Most of the area is in the Red River Valley west of Interstate Highway 29, midway between Grand Forks and Fargo. The region encompasses several small agricultural communities and contains two study areas: Galesburg and Blanchard.

The Galesburg study area consists of 102 contiguous sections or portions of sections located at the juncture of Traill, Steele, and Cass counties. The towns of Galesburg and Clifford are on the eastern perimeter of the study area. The South Branch of the Goose River flows through the northwestern part of the study area.

Table 2-1

CRS STUDY REGIONS AND AREAS

North Dakota-North

Dahlen (Receive)

Township	Range	Sections
T. 155 N.	R. 57 W.	1-3, 8-17, 20-26, and 36
T. 155 N.	R. 56 W.	5-8, 17-20, and 29-32
T. 154 N.	R. 56 W.	5-8 and 13-36
T. 154 N.	R. 57 W.	25, 26, 35 and 36
T. 153 N.	R. 56 W.	1-18
T. 153 N.	R. 57 W.	1, 2, and 11-14

Goose River (Receive)

Township	Range	Sections
T. 148 N.	R. 55 W.	5 and 6
T. 148 N.	R. 56 W.	1-5
T. 149 N.	R. 55 W.	16-21 and 27-34
T. 149 N.	R. 56 W.	2-11, 13-29, and 32-36
T. 149 N.	R. 57 W.	1-5 and 8-12
T. 150 N.	R. 55 W.	4-9 and 17-19
T. 150 N.	R. 56 W.	1, 2, and 7-35
T. 150 N.	R. 57 W.	1, 2, 9-17, 20-29, and 32-36
T. 151 N.	R. 55 W.	31-33

North Dakota-South

Galesburg (Receive)

Township	Range	Sections
T. 145 N.	R. 54 W.	1-3, 9-17, 20-29, and 32-36
T. 145 N.	R. 53 W.	7, 15-22, and 27-34
T. 144 N.	R. 55 W.	1
T. 144 N.	R. 54 W.	1-17, 20-28, and 33-36
T. 144 N.	R. 53 W.	4-9, 16-21, and 28-33
T. 143 N.	R. 53 W.	4-9
T. 143 N.	R. 54 W.	1-3, 11, and 12

Table 2-1 (Continued)

Blanchard (Receive)

Township	Range	Sections
T. 145 N.	R. 51 W.	4-9, 16-21, and 27-34
T. 144 N.	R. 51 W.	4-10, 15-22, and 27-35
T. 144 N.	R. 52 W.	1, 12-15, 22-28, and 33-36
T. 143 N.	R. 52 W.	1-4 and 9-12
T. 143 N.	R. 51 W.	2-11

Minnesota-North

Thief River Falls (Receive)

Township	Range	Sections
T. 154 N.	R. 47 W.	12, 13, 24, 25, 36
T. 154 N.	R. 46 W.	7-36
T. 154 N.	R. 45 W.	7-11, 14-23, and 26-36
T. 153 N.	R. 47 W.	1, 12, 13, 24, 25, 36
T. 153 N.	R. 46 W.	All
T. 153 N.	R. 45 W.	All
T. 153 N.	R. 44 W.	3-10, 15-22, and 27-34
T. 154 N.	R. 44 W.	31-34
T. 152 N.	R. 47 W.	1 and 12
T. 152 N.	R. 46 W.	1-12
T. 152 N.	R. 45 W.	1-10

Minnesota-South

Wheaton North (Transmit)

Township	Range	Sections
T. 130 N.	R. 46 W.	36
T. 130 N.	R. 45 W.	31 and 32
T. 129 N.	R. 46 W.	1, 11-15, 22-27, and 34-36
T. 129 N.	R. 45 W.	5-8, 16-21, and 28-33
T. 128 N.	R. 46 W.	1-3
T. 128 N.	R. 45 W.	5-8, 17, 18, and 20

Table 2-1 (Concluded)

Wheaton Southeast (Transmit)

Township	Range	Sections
T. 125 N.	R. 45 W.	1-4 and 9-11
T. 126 N.	R. 45 W.	16, 21-23, 25-28, and 33-36

Wheaton Southwest (Transmit)

Township	Range	Sections
T. 126 N.	R. 48 W.	12-14, 14, 23-26, 35, and 36
T. 126 N.	R. 47 W.	4-10, 15-22, 27-34
T. 125 N.	R. 48 W.	1, 2, 11, and 12
T. 125 N.	R. 47 W.	3-10

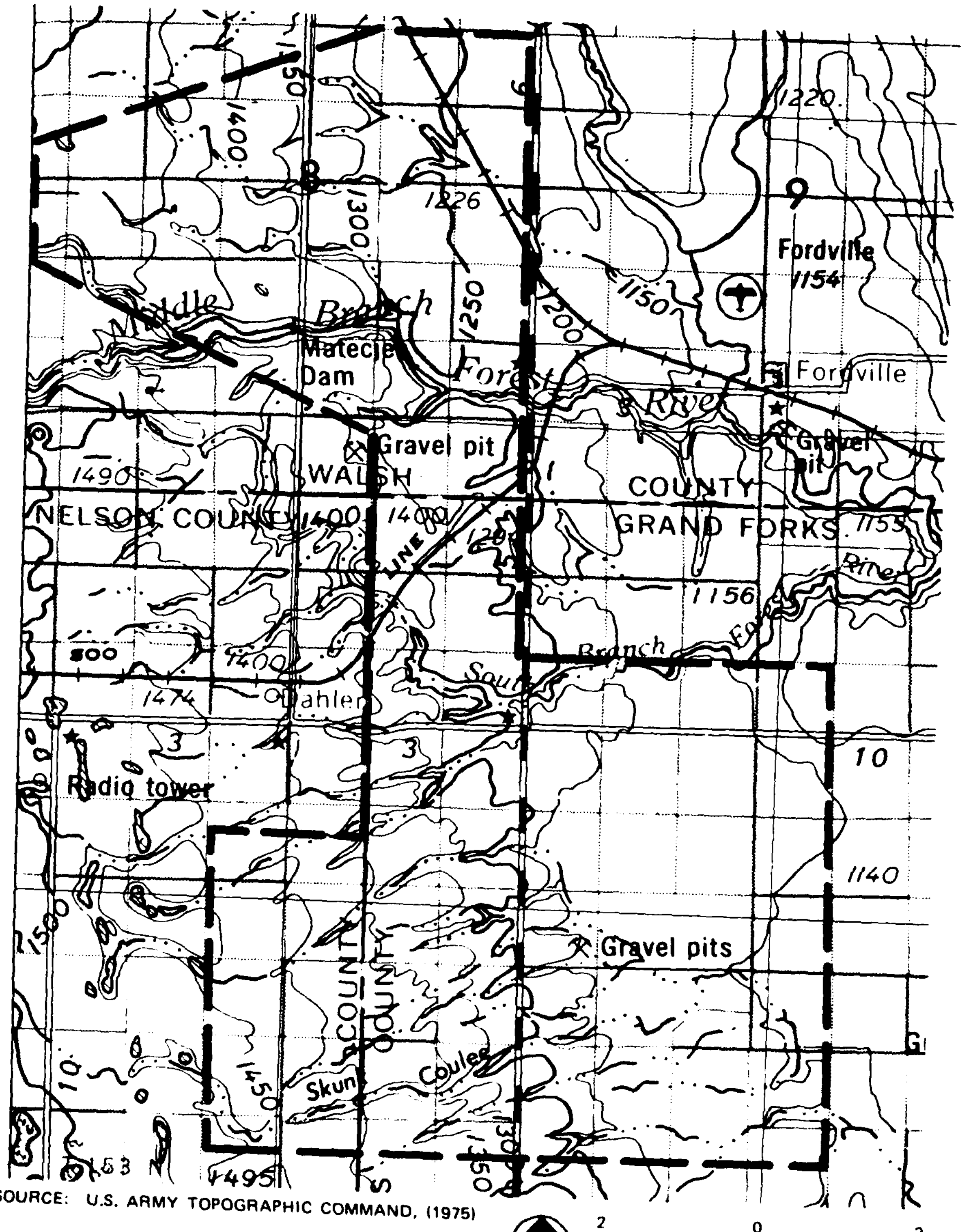
South Dakota

Amherst (Transmit)

Township	Range	Sections
T. 127 N.	R. 60 W.	25 and 36
T. 127 N.	R. 59 W.	25-36
T. 126 N.	R. 60 W.	1, 12, 13, 24, 25, and 36
T. 126 N.	R. 59 W.	All
T. 125 N.	R. 60 W.	1, 12, 13, 24, 25, and 36
T. 125 N.	R. 59 W.	All
T. 124 N.	R. 59 W.	1-6, 8-16, 22-27, 34-36
T. 123 N.	R. 59 W.	1 and 2

Grand Forks Air Force Base (Operations Center)

Township	Range	Sections
T. 152 N.	R. 53 W.	11, 14, 23-27, and 34-36

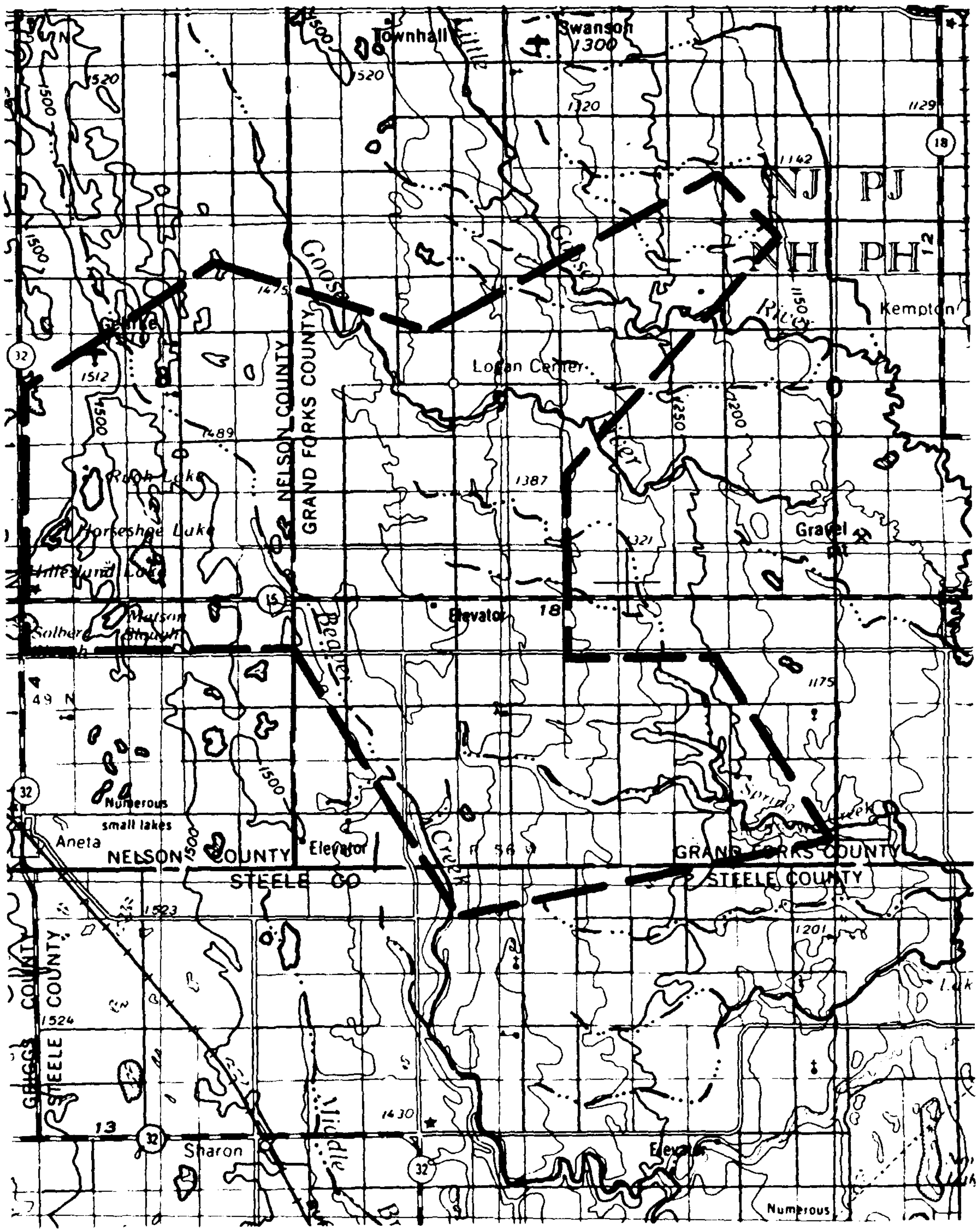


SOURCE: U.S. ARMY TOPOGRAPHIC COMMAND, (1975)

2 0 2

SCALE IN MILES
(1:125,000 Scale)

FIGURE 2-7 DAHLEN STUDY AREA



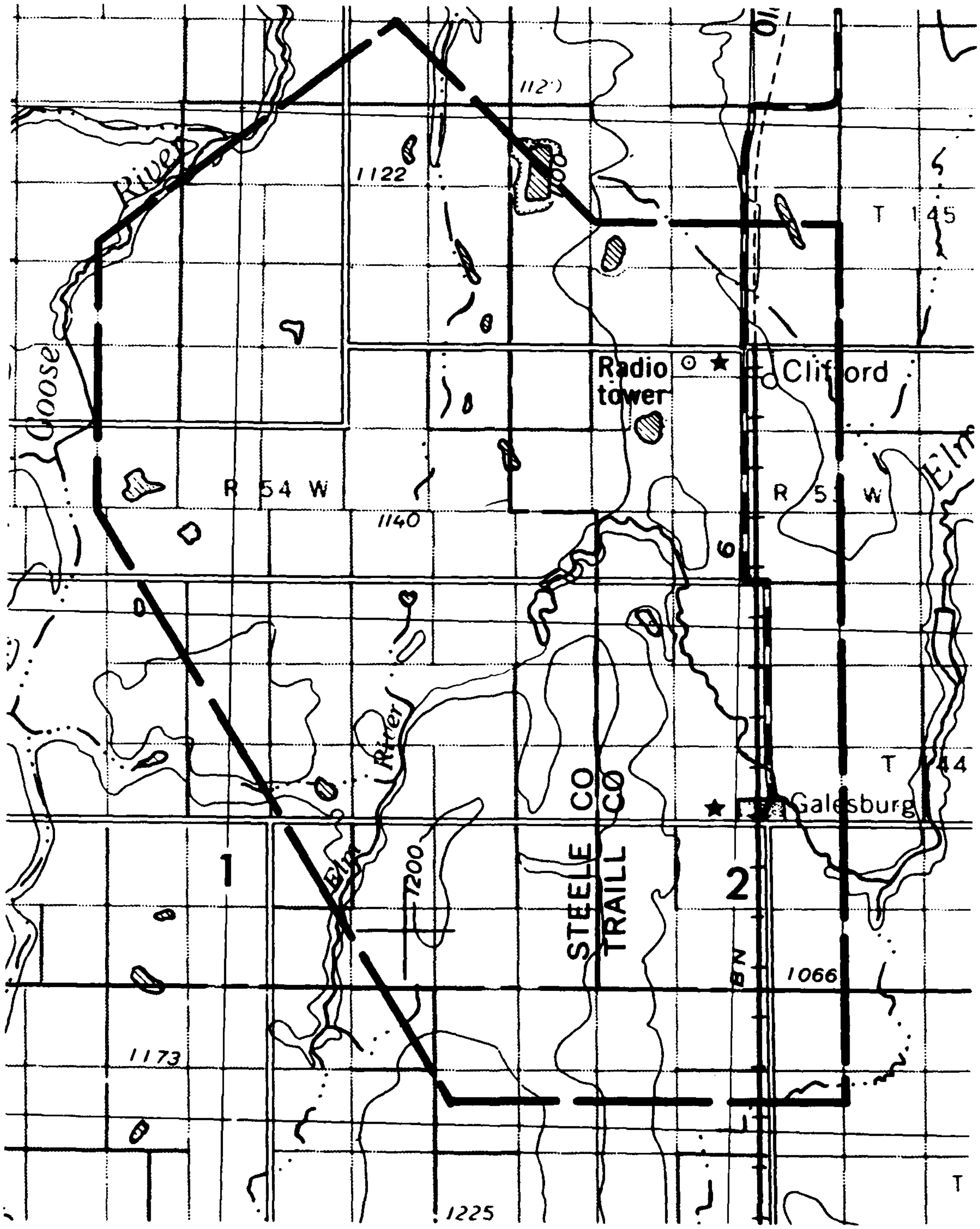
SOURCE: U.S. ARMY TOPOGRAPHIC COMMAND, (1975)

3 0 3

SCALE IN MILES

(1:189,400 Scale)

FIGURE 2-8 GOOSE RIVER STUDY AREA

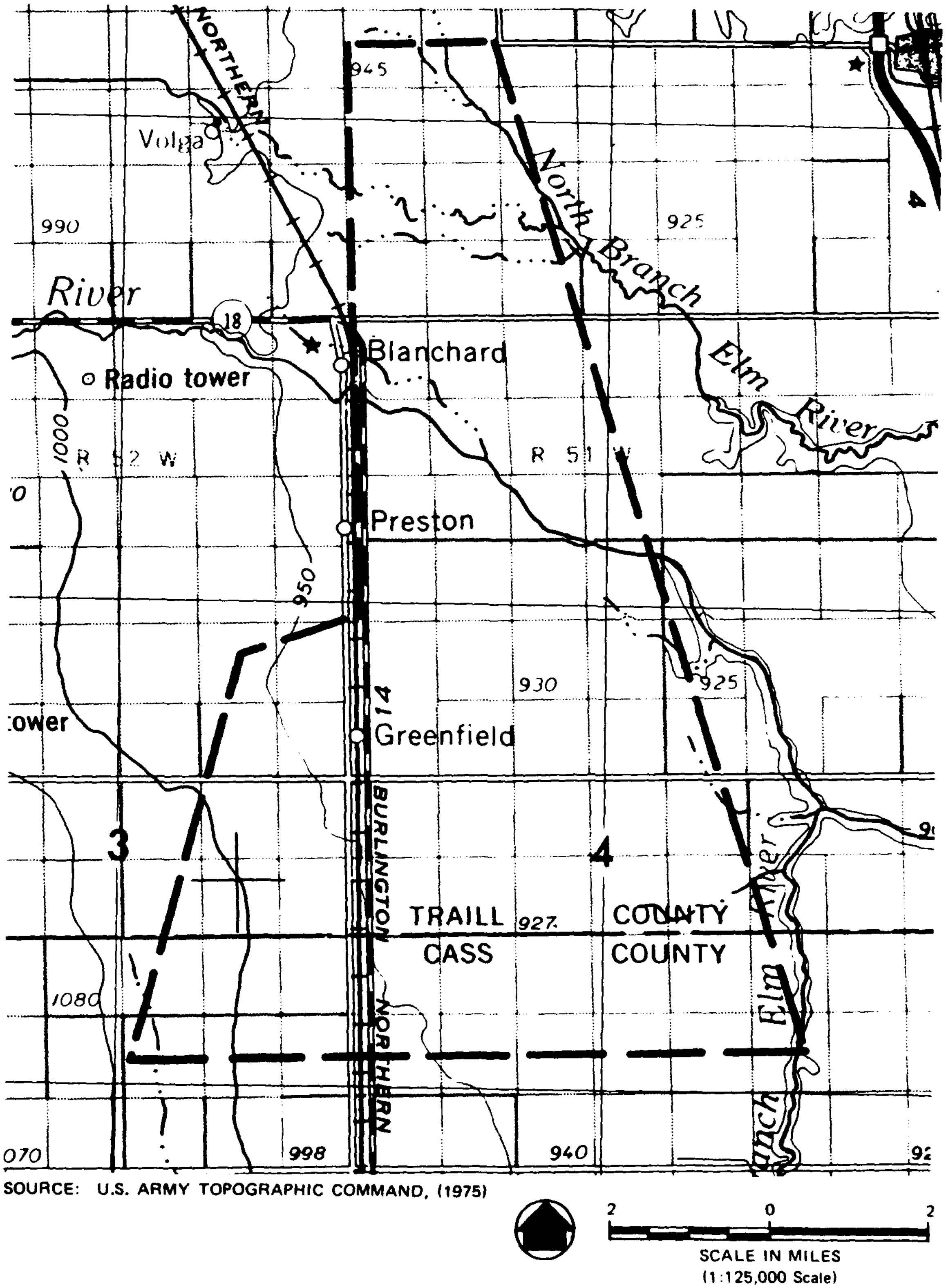


SOURCE: U.S. ARMY TOPOGRAPHIC COMMAND, (1975)

2 0 2

SCALE IN MILES
(1:125,000 Scale)

FIGURE 2-9 GALESBURG STUDY AREA



SOURCE: U.S. ARMY TOPOGRAPHIC COMMAND, (1975)

FIGURE 2-10 BLANCHARD STUDY AREA

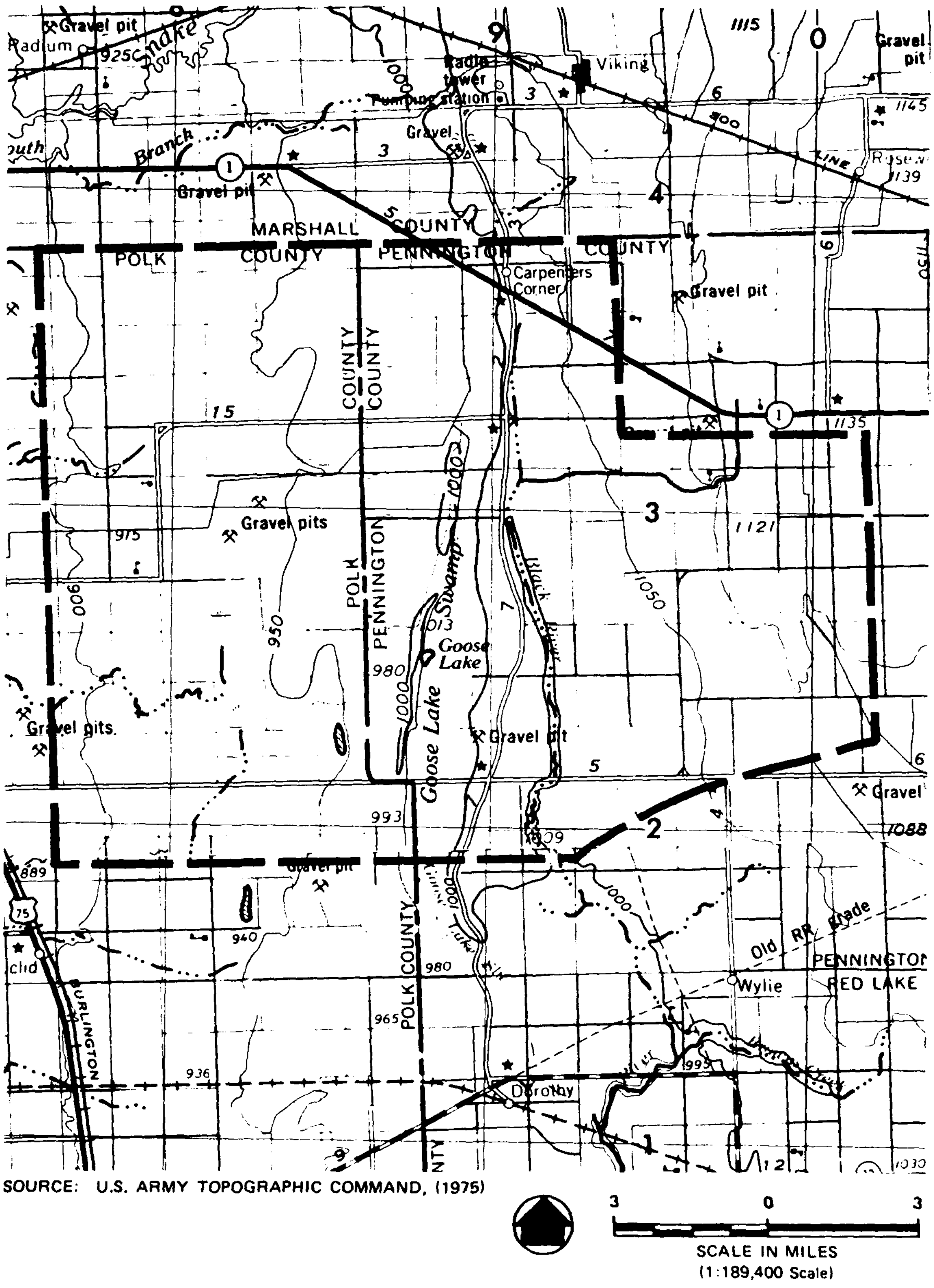
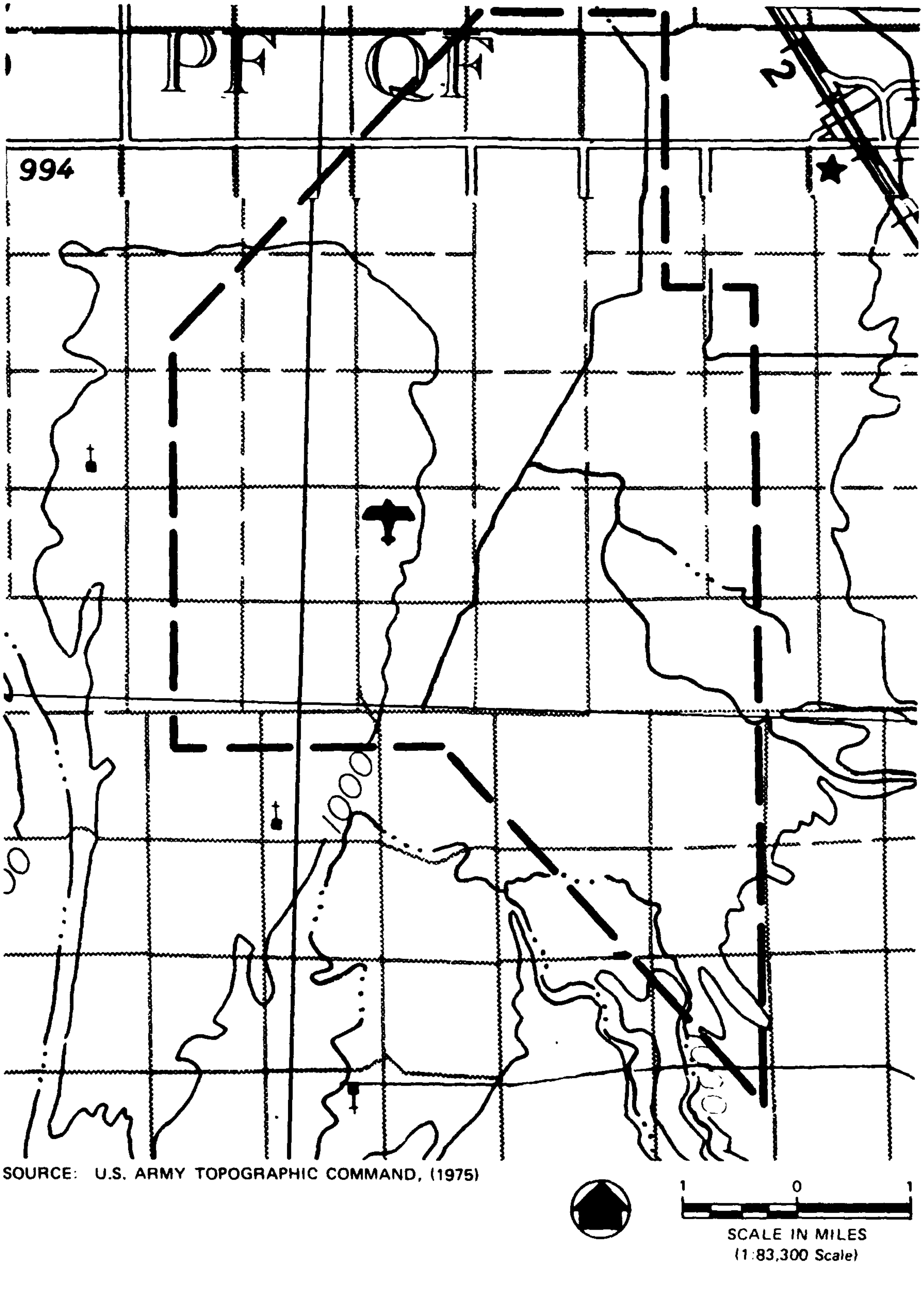


FIGURE 2-11 THIEF RIVER FALLS STUDY AREA



SOURCE: U.S. ARMY TOPOGRAPHIC COMMAND, (1975)

FIGURE 2-12 WHEATON NORTH STUDY AREA

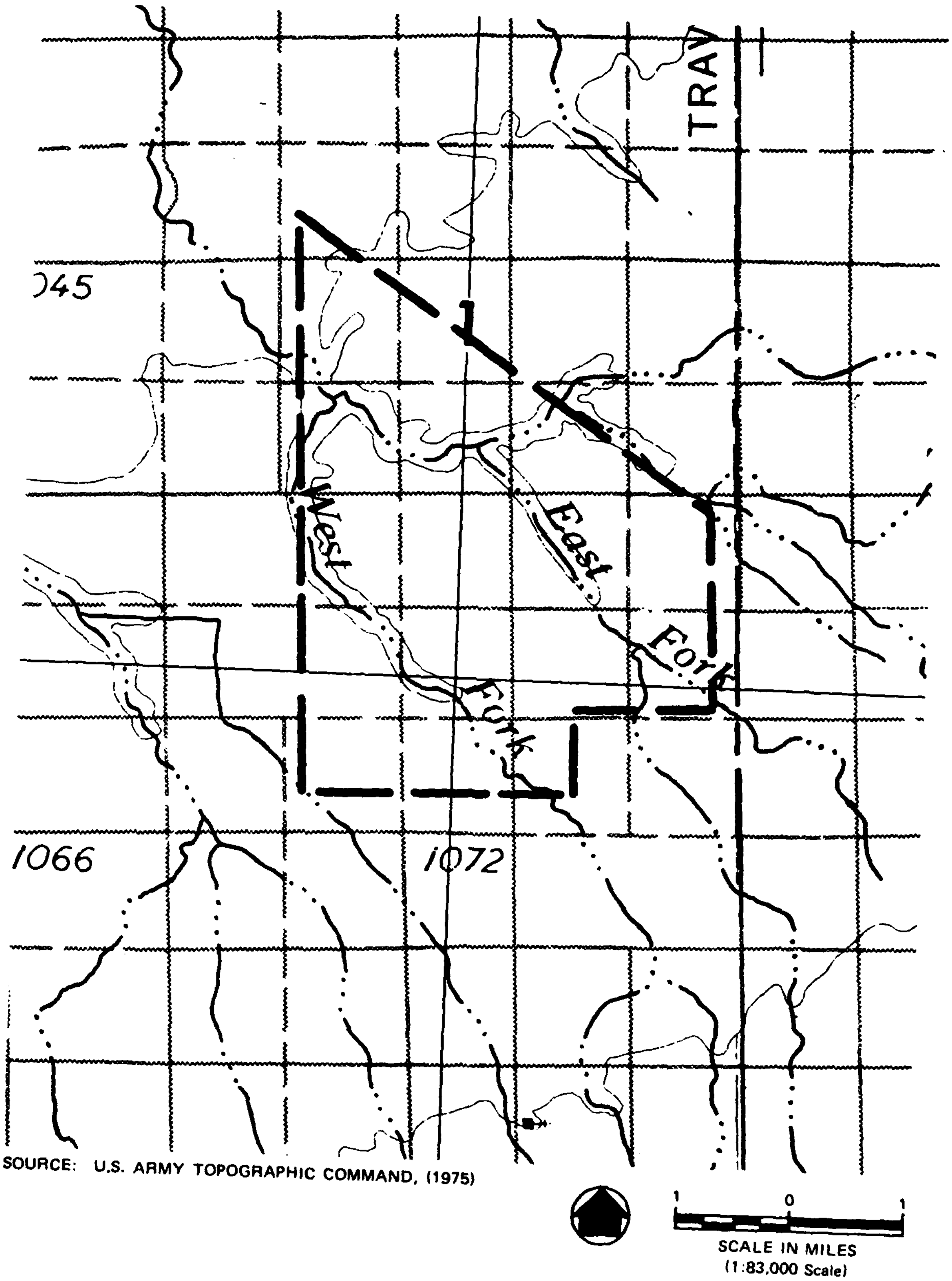
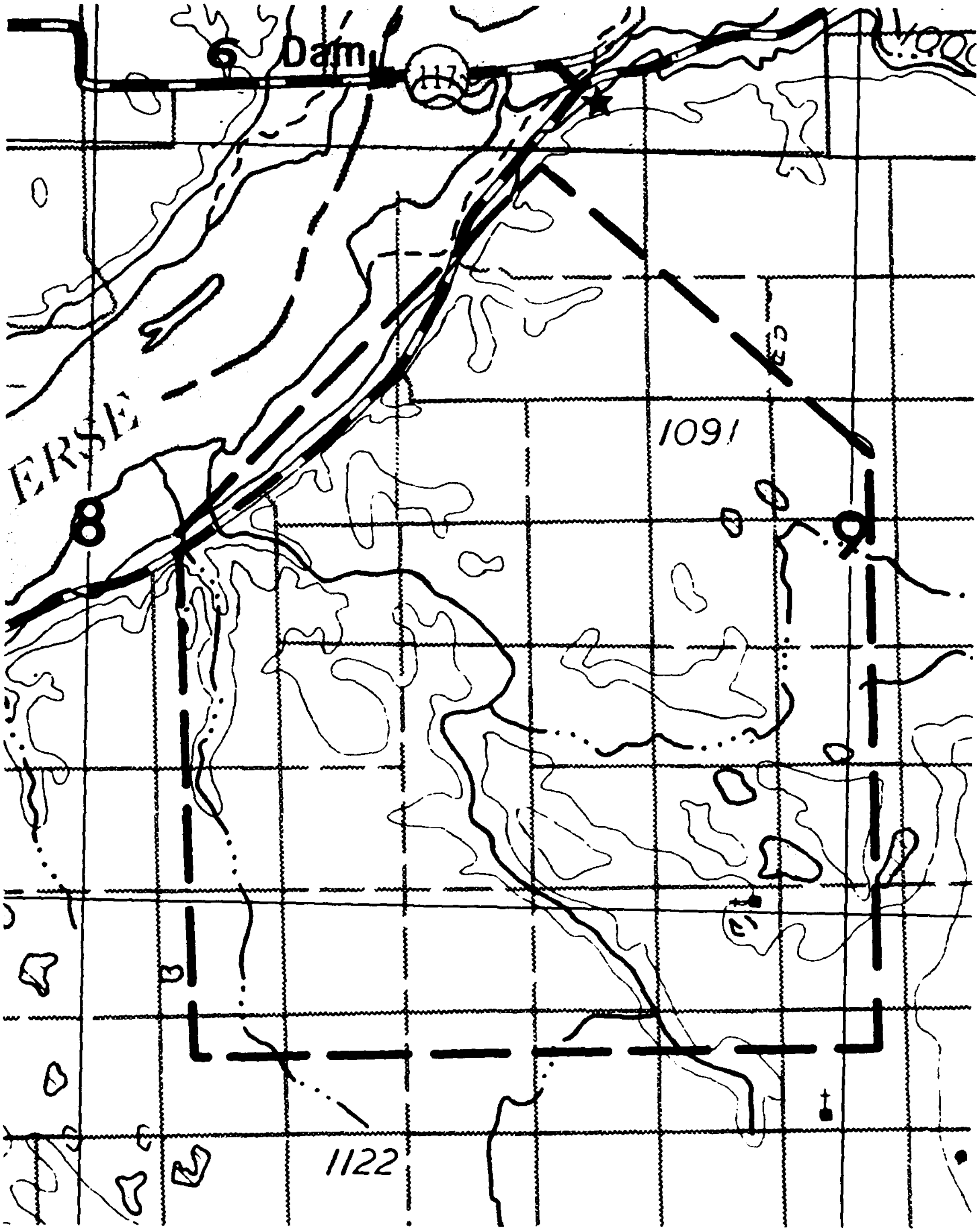


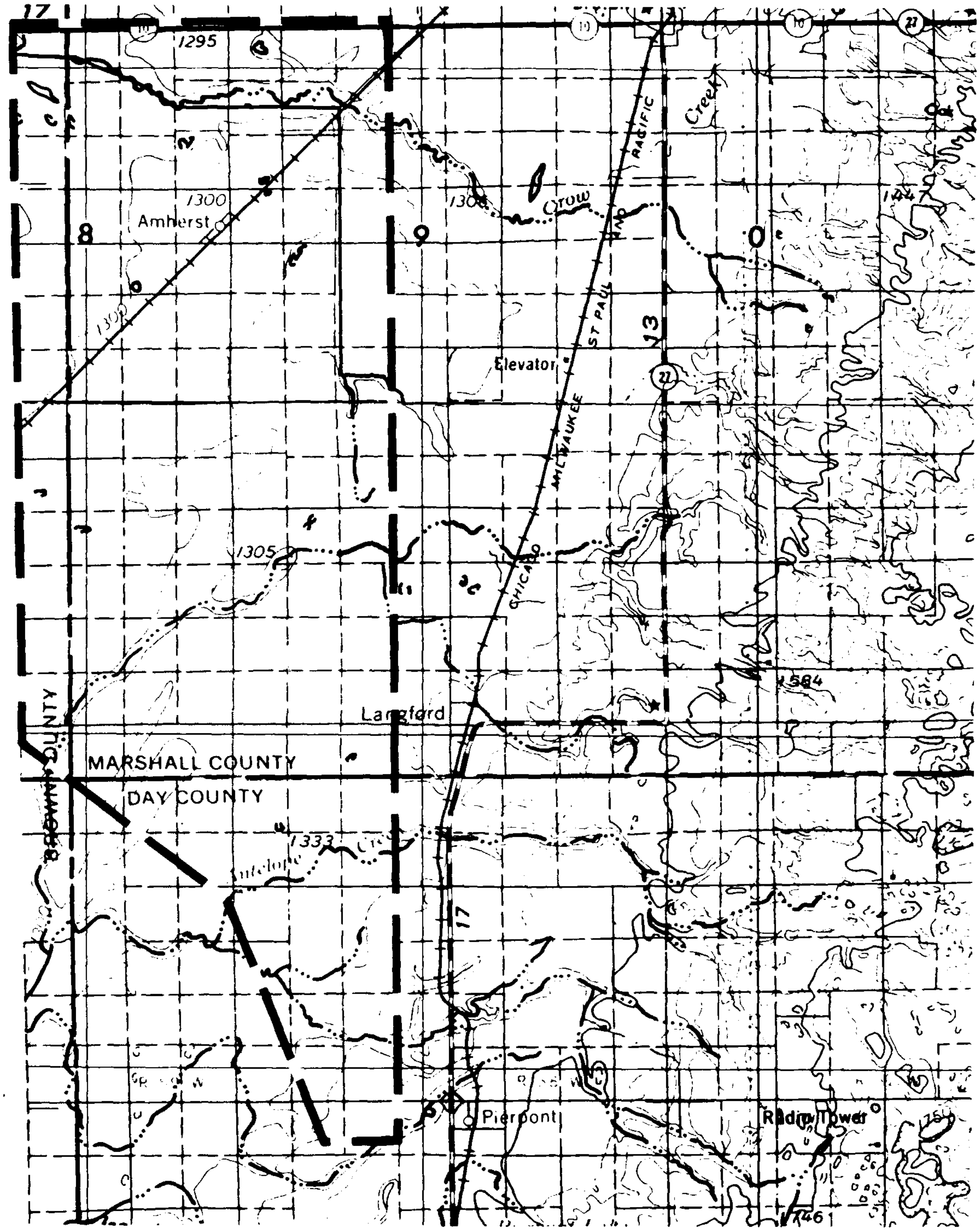
FIGURE 2-13 WHEATON SOUTHEAST STUDY AREA



SOURCE: U.S. ARMY TOPOGRAPHIC COMMAND, (1975)

SCALE IN MILES
(1:83,300 Scale)

FIGURE 2-14 WHEATON SOUTHWEST STUDY AREA



SOURCE: U.S. ARMY TOPOGRAPHIC COMMAND, (1975)

3 0 3

SCALE IN MILES
(1:189,400 Scale)

FIGURE 2-15 AMHERST STUDY AREA

The Blanchard study area consists of 78 contiguous sections or portions of sections located several miles southwest of Hillsboro in southern Traill and northern Cass counties. Interstate 29 parallels the eastern limits of Blanchard 5 miies to the east. The Elm River bisects the area.

2.1.2.2.3 Minnesota-North Region (Thief River Falls)

This region consists of one study area west of Thief River Falls, Minnesota, covering approximately 174 mi^2 in Polk and Pennington counties, Minnesota. This study area comprises 196 contiguous sections or portions of sections. Within the study area, Carpenters Corner is the only town. Thief River Falls is 3 miles east of the area.

2.1.2.2.4 Minnesota-South Region

The Minnesota-S region lies completely in Traverse County. The southern extent is 4 miles north of the Big Stone County line. The eastern extent borders the Stevens and Grant county lines. The northern extent borders the Wilkin County line. The southwestern edge is adjacent to Lake Traverse. The remainder of the western boundary is approximately 4 miles east of the Bois de Sioux River. The region consists of three study areas around Wheaton, Minnesota.

The Wheaton N study area covers approximately 37 mi^2. This is the northernmost area in the Minnesota-S region. No towns are in the study area, but Tintah is 1 mile east. The South Fork of the Rabbit River flows through the study area. The western extent of the area is 5 to 6 miles east of Bois de Sioux River. Wheaton-N comprises 40 contiguous sections or portions of sections.

The Wheaton SE study area covers approximately 18 mi^2. The eastern edge borders the Traverse/Stevens county line. No towns are located in this study area. Dumont is 4 miles to the west. Several drainages bisect this study area, including the West Fork, East Fork, and the main stem of Twelvemile Creek. Lake Traverse is approximately 16 miles west of Wheaton SE. Wheaton SE consists of 20 contiguous sections or portions of sections in Traverse County.

The Wheaton SW study area covers approximately 32 mi^2. The northwestern edge bounds Lake Traverse, with drainages crossing through the study area. Wheaton is approximately 5 miles northeast, and Browns Valley is 8 miles southwest. Dumont is 6 miles east. The Wheaton SW study area comprises 36 contiguous sections or portions of sections in Traverse County.

2.1.2.2.5 South Dakota Region (Amherst)

This region consists of one study area in South Dakota near Amherst in Brown, Day, and Marshall counties. Aberdeen, the nearest city, is located 35 miles to the southwest.

2.1.2.2.6 Grand Forks Air Force Base

Located just to the west of Grand Forks, Grand Forks Air Force Base (AFB) has been proposed as the operations center for the CRS.

2.1.2.3 Siting Alternatives

Because of the various distance requirements, not every one of the five receive study areas can be paired with every transmit study area. Table 2-2 shows the possible combinations. Eighteen pairs are possible, although, in three cases (as noted) the study areas are at the maximum acceptable distances from one another.

In choosing transmit and receive site locations, the Air Force would select one of the pairs listed in Table 2-2. Its choice would be based on operational, engineering, cost, and land availability considerations, as well as on environmental impacts.

Table 2-2

FEASIBLE PAIRINGS OF TRANSMIT-RECEIVE STUDY AREAS

	Transmit Areas			
Receive Areas	Amherst	Wheaton N	Wheaton SW	Wheaton SE
Dahlen	*	*	No	No
Goose River	Yes	Yes	Yes	Yes
Blanchard	Yes	Yes	Yes	Yes
Galesburg	Yes	Yes	Yes	Yes
Thief River Falls	*	Yes	Yes	Yes

*The study areas in this pair are at the maximum acceptable distance from one another. Portions of the areas might be too far apart.

2.2 Alternatives

2.2.1 No Action or Postponement of Action

In the no-action alternative, the CRS would not be constructed at any of the study areas. Until the decision was made to proceed, the alternative of postponing construction of the CRS would be equivalent to the no-action alternative.

No alternative means of radar surveillance and tracking will be available in the foreseeable future to substitute for the OTH-B radar. Therefore, because the threat from aircraft approaching North America remains significant, the U.S. would need to continue to compensate in its defensive military strategies for the lack of information that the OTH-B radar could provide.

2.2.2 Other Surveillance Systems

2.2.2.1 Aircraft Systems

The Air Force operates surveillance aircraft known as Airborne Warning and Control Systems (AWACS) that can track both aircraft and marine vessels. One possible alternative to the OTH-B system is a fleet of AWACS aircraft. However, each aircraft costs approximately $135 million. The cost to purchase, man, base, and operate the large number of aircraft required to match the proposed OTH-B coverage would be significantly more than the cost of the CRS.

2.2.2.2 Satellite Systems

The use of surveillance satellites is conceptually possible, but significant technical advances would be required to develop a wide-area surveillance system to detect aircraft and cruise missiles. New technology would be required for both satellite-borne surveillance equipment and computer systems to analyze and relay data received by the satellites. Consequently, satellite detection systems are not a feasible alternative to the OTH-B systems.

2.3 Comparison of the Environmental Consequences of the Alternatives

Section 3 describes each study area in detail. Section 4 sets forth the impacts of constructing and operating the CRS. This section focuses on the difference in impacts among the transmit study areas and among the receive study areas.

The alternatives to the proposed action (other than geographic alternatives) were described in Section 2.2. Neither airborne nor satellite surveillance systems are practical alternatives to the OTH-B system. Therefore, the impacts associated with these alternatives were not assessed and cannot be compared with the impacts from constructing and operating the CRS.

The alternatives of no action or postponement of action would avoid or defer the environmental impacts anticipated with construction and operation of the CRS. Deferral is usually considered when the possibility exists that some feature of the proposed action or the setting in which it would take place is likely to change in such a way that environmental impacts would be lessened. No such changes are expected in this situation. Consequently, taking no action would avoid the expected CRS impacts, and deferring action would postpone them, but no basis exists for expecting the impacts to become less significant.

2.3.1 Receive Study Areas

The major factors that differentiate the receive study areas from one another are topography, surface water features, vegetation, and wildlife. The more rugged topography at Dahlen and Goose River would probably lead to greater impacts because of the need for more earth-moving and grading. These activities would increase the potential for erosion and contamination of rivers and streams.

Problems with surface water would be greatest for the Dahlen, Goose River, and Galesburg areas, and would affect existing drainage patterns, wetlands, and associated wildlife. Impacts would be of much less consequence in the western portion of the Thief River Falls study area than in the eastern portion, yet proximity to attractive habitats makes the western part somewhat sensitive and limits acceptable locations there. The Blanchard study area has the fewest wetlands and thus would have the fewest associated wildlife impacts, if the receive antennas were sited away from the Elm River. No impact to threatened or endangered species would occur in any of the receive study areas.

The combined biophysical impacts that would be caused by grading requirements and surface erosion, by disruption of surface water bodies, and by the loss of vegetation and wildlife habitats would be significantly greater for the Dahlen, Goose River, and Galesburg study areas. The presence of the Central Flyway and of abundant bird breeding and feeding grounds give these study areas the highest potential for bird collisions with the antenna structure and backscreen. The Blanchard and Thief River Falls study areas would have fewer biophysical impacts because they are flatter and have fewer surface water bodies. While mitigation measures, including the careful selection of the site, would avoid or reduce the impacts, proximity to sensitive wildlife areas in the Thief River Falls study area could make that area somewhat less acceptable than an appropriate site within the Blanchard study area.

Removal of land from the tax base of local districts could be a negative impact on any selected area and would depend on the extent to which land is leased or purchased. A slight positive impact from reduction of unemployment in Thief River Falls might occur. This discussion is summarized in Table 2-3.

Table 2-3

MOST SIGNIFICANT POTENTIAL IMPACTS
AT RECEIVE STUDY AREAS

	Study Area				
Impact Factor*	Dahlen	Goose River	Galesburg	Blanchard	Thief River Falls
Grading requirements and potential for erosion	--	--	-	o	o
Unavoidable presence and disruption of surface water	--	--	--	o	o
Loss of vegetation and wildlife habitats	--	--	--	o	-
Bird collisions	--	--	-	-	--
Reduction in unemployment	o	o	o	o	(+)
Loss of district tax revenues	-	-	-	-	-

Key:
- -- significant negative impact
- - negative impact
- (-) possible negative impact
- o minor impact or no impact
- (+) possible positive impact

*Most factors depend on specific site location within the study area.

2.3.2 Transmit Study Areas

2.3.2.1 Biophysical and Socioeconomic Effects

The Wheaton SW study area, which is adjacent to Lake Traverse, is sensitive because of its wildlife and surface water features. Surface water, vegetation, and wildlife would not be significantly impacted in the Wheaton N study area. The biological impacts in the Amherst area would be similar to those at the Wheaton N area if the antennas were sited away from certain sensitive areas. The impacts at Wheaton SE would be intermediate in severity. No threatened or endangered species is known to inhibit any of the transmit study areas.

The economic consequences at each study area would be similar but would be focused on the communities near the selected study area (e.g., Wheaton or Aberdeen). Because farm income per acre is lower in the Amherst study area than near Wheaton, minor differences in economic impacts could occur.

Information about potentially important cultural resource properties suggests that the Wheaton SW study area is more sensitive than the other areas.

The Amherst and Wheaton N study areas are the environmentally preferred areas for the transmit arrays. These study areas would have very few biophysical impacts, which could be easily mitigated by proper selection of a site away from the few wet areas and wildlife habitats. The Wheaton SW study area would have significantly greater biophysical impacts than would any other transmit study area. The potential for bird impacts, present for all study areas, would be highest at the Wheaton SW study area.

Economic data from the past several years and comments at scoping meetings suggest that there would be greater economic and social impact from removal of productive farm land in the Wheaton areas. For all study areas, loss of tax revenue as discussed above for receive study areas is also a potential negative impact. The potential significant impacts at transmit study areas are summarized in Table 2-4.

2.3.2.2 Electromagnetic Interference and Hazards

Available information indicates no factors that would allow discrimination among the study areas with respect to electromagnetic interference and hazard effects, except in one respect: the potential for such interference and hazards exists only near the transmit site.

Interference with amateur radio, air navigation, air or land mobile communication, or reception of broadcast television or international broadcast radio is unlikely. No hazard associated with fuel handling or the use of cardiac pacemakers would exist beyond the exclusion fence. The radar would not interfere with reception of broadcast radio in any area beyond about 1 to 2 miles from the transmit arrays.

Table 2-4

MOST SIGNIFICANT POTENTIAL IMPACTS
TRANSMIT STUDY AREAS

Impact Factor*	Study Area: Wheaton N	Wheaton SE	Wheaton SW	Amherst
Unavoidable presence and disruption of surface water	o	(-)	--	-
Loss of vegetation and wildlife habitats	o	o	-	(-)
Bird collisions	-	-	--	-
Loss of productive farmland	--	--	--	-
Loss of district tax revenues	-	-	-	-
Disturbance of cultural resources	o	o	-	o

Key:
- -- significant negative impact
- \- negative impact
- (-) possible negative impact
- o minor impact or no impact
- (+) possible positive impact

*Most factors depend on specific site location within the study area.

Safe separation distances between the transmit arrays and electroexplosive devices would depend on the electrical conductivity of the ground. Available information is adequate to make preliminary estimates of these distances only, and is not adequate to differentiate among the transmit study areas.

2.3.2.3 Radiofrequency Radiation Health Hazards

The RFR emitted by the CRS would be independent of the transmit study area selected. The distance of the exclusion fence from each transmit array would be chosen so that, for any specific site within any transmit study area, the maximum average power density beyond the exclusion fence would be below the American National Standards Institute (ANSI) 1982 standard for both occupational and general public exposure to RFR. Review of the relevant literature on biological effects indicated that no reliable scientific evidence exists to suggest that chronic exposure to the RFR levels below this standard would be deleterious to the health of even the most susceptible members of the population.

2.4 Long-Term Implications

If the proposed action is implemented, some adverse impacts that cannot be avoided would result from construction and operation of the CRS facilities. Some productive farm land and wildlife habitat would be removed, and some wetlands may be permanently lost. However, with appropriate mitigation measures, these impacts would be small. For instance, the area within the exlusion fences could be planted in native prairie grasses to provide new habitat. Loss of shelter breaks could be balanced by planting of new ones. Some birds may be lost from collision with the antenna arrays, but careful site selection and other mitigation measures could reduce such loss.

The proposed construction of the CRS would require materials and energy, as well as land. The commitments of energy would be irreversible and irretrievable. This would also be true for most materials. The land on which the major CRS structures are to be built may be irreversibly and irretrievably committed because of the expense of removing the antenna structures, buildings, and other improvements. However, this land is a small fraction of the total land required. Most of the required land could be returned to productive use, and the long-term productivity of the environment would be only slightly diminished.

3 AFFECTED ENVIRONMENT

3.1 Introduction

This section describes the current environment of the locations being considered for the CRS. This description forms the baseline from which potential impacts, described in Section 4, can be estimated and described. The section begins with the physical environment, describes the biological, socioeconomic, aesthetic, and cultural environments, and concludes with a discussion of the electromagnetic environment. The organization of Section 4 parallels that of this section so that readers can focus on topics of particular interest and note their impact in the subsequent section.

This section is organized by environmental topic and discussions of the study regions and study areas are subordinate to these topics. Whenever possible, characteristics applicable to several study areas are presented on a regional basis to avoid repetitious discussion for each study area.

Finally, a glossary is provided (preceding Section 1) to assist with technical or scientific terms that are used to describe the environment and the impacts.

3.2 Land and Minerals

3.2.1 Overview

The nine study areas and the operations center site fall within the boundaries of the Central Lowland Physiographic Province (Atwood, 1940). It is a glaciated area covered with till, lake sediments, and glacio-fluvial sand and gravel deposits. The land slopes gently from its western and eastern margins towards the Red River Valley, which drains to the north. Much of the drainage is poorly developed and includes basins with no exterior drainage varying from a few acres to many square miles.

3.2.2 Geology

3.2.2.1 Dahlen, Goose River, and Galesburg

These study areas are located on or adjacent to the Drift Prairie that occupies part of the Central Lowland. The Drift Prairie, which extends north into Canada and south into South Dakota, is characterized by flat to gently rolling topography that can be locally rugged. It

is bounded on the west by the Missouri Escarpment in central North Dakota and on the east by the Pembina Escarpment, which forms the western edge of the Red River Valley. The Drift Prairie is made up of various glacial deposits including moraines and outwash deposits. Cumulatively, the deposits are as much as 300 ft thick and average more than 100 ft thick (Bluemle, 1967, 1973, 1975, 1977).

Bedrock consists of Mesozoic strata that dip gently to the west. Chief among these are the Cretaceous Pierre, Niobrara, Carlisle, and Greenhorn formations, all of which are shales derived from marine sediments (Bluemle, 1982). Underlying these strata are Precambrian basement rocks that are principally low-grade schists and gneisses in the northwest and granite in the southeast.

3.2.2.2 Blanchard, Thief River Falls, and Amherst

These study areas, although geographically separated, have similar surficial geology and hence are grouped together in this subsection. The surficial geology of these study areas is a product of sediment deposition in lakes formed from glacial meltwater. The Blanchard and Thief River Falls study areas are located on the glacial Lake Agassiz Plain physiographic division, and the Amherst study area is located on the Lake Dakota Plain physiographic division.

Both of the ancient lakes, Dakota and Agassiz, occupied significant areas. In the case of Lake Agassiz, the area amounted to many thousands of square miles and extended into what is now Canada. Deposition and accumulation of sediment left deep deposits of silt and clay, 100 ft thick in Lake Dakota (Koch, 1975; Koch et al., 1976) and 300 ft thick in Lake Agassiz. Changes in lake levels produced new shorelines where wave action modified the existing till. Such modifications occurred at the Thief River Falls study area, where the moraine deposits have been mixed and thinly covered with lake sediment, and beach strand lines have been created.

All three study areas have a similar bedrock profile even though they are separated by considerable distances. Underlying the Pleistocene glacial deposits are successive layers of shallowly dipping Cretaceous marine strata. These beds are fine grained and are known to frequently contain potentially expansive bentonite layers. Underlying the Cretaceous strata are Paleozoic and Precambrian basement rocks including metasedimentary rocks, amphibole schists, and granite.

3.2.2.3 Wheaton N, Wheaton SE, and Wheaton SW

These study areas are located near the southern end of the Lake Agassiz Plain. Wheaton N and Wheaton SW study areas are just within the lake boundary, and their surficial geology includes lake-modified till (Hobbs et al., 1982). The Wheaton SE study area is outside the boundary,

on the Olivia Till Plain, and contains deposits included in the Big Stone Moraine association. These deposits are of two types, ground moraine and stagnation moraine. The latter are coarser and more free draining than the former.

The bedrock geology at these three study areas is quite similar to that at the other study areas in that it is underlain by Cretaceous Marine Shale Strata (Sims, 1970; Sims et al., 1972). These rocks are in turn underlain by Precambrian basement rocks, including intrusive and metasedimentary rocks, the presence of which has been inferred from gravity and aeromagnetic data.

3.2.2.4 Grand Forks AFB

Surficial geology includes approximately 250 ft of glacially derived drift resting on bedrock (Hansen et al., 1970). The drift accumulation represents at least three glaciations prior to the deposition of the surficial till and lake units.

Beneath the glacial drift are sedimentary rocks, chiefly shale and sandstone, but also some limestone. These rocks are Cretaceous and Ordovician in age and are separated by a large unconformity. The strata dip gently to the west and rest on a similarly sloping Precambrian basement rock surface. Exploration of the basement rocks has revealed that they are granite and amphibolite, but the rock type that underlies the study area has not been specifically determined.

3.2.3 Topography and Soils

3.2.3.1 Dahlen, Goose River, and Galesburg

The Dahlen study area has moderate topographic relief, with slopes ranging from 0.5 to 1.5% in the flattest areas and extensive areas of 8% and greater slopes in the vicinity of the Middle and South Branches of the Forest River and the Skunk Coulee. Elevations range from 1,150 to 1,500 ft above mean sea level (MSL). Topographic relief in the Goose River study area generally ranges from 0.5 to 4% slopes throughout the area, with some areas of steeper relief adjacent to intermediate streams. Elevations range from 1,200 to 1,500 ft MSL. The Galesburg study area is fairly flat in its northern portion, with slopes of about 0.5%. This portion has numerous shallow depressions that are seasonal ponds. The southern portion of the area has slopes of 5 to 10%. Elevations range from 1,100 to 1,200 ft MSL.

The dominant soil groups are the Barnes-Svea association in the north and the Bohnsack-Lankin association in the south (Soil Conservation Service, 1972, 1977, 1981). Subordinate soil types include the Buse, Cresbard, and Renshaw. These soils are typically 48 to 60 inches deep. They are considered to be medium-textured, but they contain a high silt-clay content and are therefore classified as low-plasticity

silts and clays. Consequently, percolation in these soils is very poor. In general, topography permits them to be well to moderately well drained, and surface drainage limits the extent and duration of standing water. Although the soil pH is only slightly alkaline, typically 7.5, the soil is considered to be highly corrosive to uncoated steel and slightly corrosive to concrete. The seasonal high groundwater level varies between 3 and 5 ft below ground level.

The soils in these study areas are well suited to small grains such as hard wheat, durum wheat, and barley, and to other crops including flax, soybeans, and sunflowers as well as pasture.

3.2.3.2 Blanchard, Thief River Falls, and Amherst

Surface elevations at the Blanchard study area range between 900 and 1,000 ft MSL. The study area is quite flat, with slopes of 0.1%, except in the southwestern corner and along the Elm River and its tributaries, where slopes are 2 to 3%.

The soils are chiefly of the Fargo-Hegne association (Soil Conservation Service, 1977). These are nearly level, poorly drained, deep soils that are finely textured. Because of their high fines content and poor drainage, they are considered to have poor workability. Depth to seasonal high groundwater level ranges from 1 to 3 ft. The west side of the study area has some Doran-Viking association soils that are considered very similar to the Fargo-Hegne soils.

Soils in the Blanchard study area are suited to small grains, sugar beets, and grasses.

Topography in the Thief River Falls area is based on north-south trending beach strand lines of granular materials that were deposited on fine-grained lake deposits. The strand lines are a series of low linear ridges with elevations of 10 to 30 ft above the surrounding area. Slopes range from 0.5 to 4%. Surface elevations vary from 900 to 1,200 ft MSL as the study area rises from west to east. Much of the natural drainage is directed into low areas between the strand lines, such as Goose Lake Swamp. A network of ditches has been constructed to aid in draining the area.

Several soil associations occur in the study area. However, three account for the bulk of the areal coverage. The Rollins-Vallers association and the Grimstad-Rockwell-Foldahl association are similar in that they were both formed on glacial lake plains and are generally poorly drained, but locally may be well drained (Soil Conservation Service, 1984). The soils are clayey to sandy loam and are susceptible to wind erosion. A high groundwater table 1 to 3 ft below the ground surface makes for very poor percolation. The risk of corrosion to uncoated steel is high with these soils.

A third soil association is the Lohnes-Karlstad. It is developed on glacial lake beach ridges made of silty sand and gravel. Slopes range from 0 to 6%, and overall the land is well drained. The water table is generally 6 ft below the ground surface. The low water table and the granular soils allow for very rapid percolation. There is a low to moderate risk of corrosion to uncoated steel in these soils.

Soils in the Thief River Falls study area are suited to small grains, sugar beets, and grasses, and also to small wood lots containing oak and aspen.

Ground surface elevations at the Amherst study area range between 1,300 and 1,500 ft MSL, but elevation changes are so gradual that the area appears nearly level. Slopes are about 1%, except in localized areas in the north and around intermittent streams in the south.

Two soil associations dominate the site. The Embden-Hecla-Ulen association occurs on nearly level to gently undulating ground that ranges from somewhat poorly drained to well drained (Soil Conservation Service, 1975). Soils in the association are typically loamy and sandy, formed in eolian (wind-blown), lacustrine, and outwash sand. They are particularly susceptible to wind erosion. Permeability in them is high. The potential for corrosive attack of concrete or uncoated steel is considered to be low.

The other major soil association is the Beotia-Great Bend, which is found in nearly level to gently sloping ground that is characteristically well drained. Even so, the hazard of erosion is considered small or nonexistent. Soils are silty loams formed in glacial lacustrine material, which possess a moderate degree of permeability. Soil reactivity with concrete or uncoated steel is considered negligible.

Soils in the Amherst study area are suited to corn, barley, rye, oats, and alfalfa as well as pasture.

3.2.3.3 Wheaton N, Wheaton SE, and Wheaton SW

The Wheaton SE and Wheaton SW study areas are situated in a morainal area that is gently rolling and has numerous small, closed depressions. Soils derived from the moraine deposits are moderately to poorly drained. Typically, they are composed of low-plasticity, sandy and clayey silt with varying amounts of sand and gravel. Percolation in these soils is slow.

The Wheaton N study area is located on the Agassiz Lake Plain. The topography is very flat, and drainage is poor. Extensive ditching has been necessary to open this area for agricultural purposes. Soils at this site have developed from till that was washed and modified by the actions of the ancient glacial lake. They are silty clay loams with

varying sand and gravel content. Because of their high silt-clay content, these soils are fairly impermeable. Throughout the year, the groundwater table remains very near the surface. These soils are known to be alkaline and are considered to be corrosive to uncoated steel as well as concrete (Maclay et al., 1968).

The Wheaton N study area is homogeneously flat with slopes generally 0.1%. Elevations range from 990 to 1,010 ft MSL. The Wheaton SE study area is also flat, with slopes ranging from 0.25 to 0.8% except adjacent to Twelvemile Creek and its West Fork. Elevations range from 1,050 to 1,075 ft MSL. Wheaton SW is also generally flat except along Lake Traverse. In the flat areas, slopes range from 0.1 to 1.5%. Elevations range from 980 to 1,120 ft MSL.

3.2.3.4 Grand Forks AFB Operations Center

The major soil types at this site are the Gilby and Glyndon types. These soils are roughly 60 inches deep and very fine grained. Consequently, they have moderately low permeablility. Surface slopes are very shallow, and thus the soils are very poor draining.

3.2.4 Minerals

3.2.4.1 Dahlen, Goose River, and Galesburg

Because these areas are blanketed with thick deposits of glacially derived material, mineral exploitation for sand and gravel has historically been confined to these deposits and to the few rock outcrops exposed in the erosion channels of rivers and streams. Extensive mineral exploration in the area has revealed little in the way of deposits worthy of developing. Sand and gravel for use as aggregate typically contain too high a proportion of shale fragments to be acceptable (Landis, 1973; Noble, 1973). The most important resource is fill material, which is quarried in numerous pits in the surrounding area.

Mineral exploration of the bedrock has revealed no deposits warranting mining and extraction. Limestone for cement production has been quarried in the past. However, this practice was abandoned in favor of better quality material imported from sources outside the area.

3.2.4.2 Blanchard, Thief River Falls, Amherst

The abundant clay deposits at the study areas have been examined in the past by various agencies to determine their commercial value. Some clay has been mined for brickmaking, but clay deposits located elsewhere are richer in kaolinite and have proved to be more attractive. Consequently, no active clay extraction exists at any of the study areas. Sand and gravel are for the most part absent at the Blanchard and Amherst study areas (Koch, 1975). Construction sand and gravel are

available at Thief River Falls in the beach lines, where wave action from the glacial lake washed out the fine materials. Extensive mineral exploration of the underlying bedrock has taken place, but no deposits of importance have been identified to date.

3.2.4.3 Wheaton N, Wheaton SE, and Wheaton SW

The areas have been explored for minerals. To date, no important mineral sources have been identified other than low-grade sand and gravel for fill.

3.2.4.4 Grand Forks AFB

Important deposits of sand and gravel occur in the vicinity and are heavily exploited. The presence of shale in the gravel makes much of it unsuitable for use as concrete aggregate.

3.2.5 Seismology

The tri-state region in which the study areas are located is situated within the tectonically stable interior of the North American continent. The region is seismically quiet, and earthquakes are weak and infrequent. Since the middle 1800s, approximately 18 earthquakes have been recorded in the region (Mooney and Morey, 1981). Because of the late and generally sparse settlement of the region by European immigrants, it is possible that other earthquakes went undetected. The maximum reported Richter magnitude for a seismic event in the region is 4.8, and several 4.6 magnitude quakes have also been recorded. In addition to the regional earthquakes, seismic events outside the region, such as Montana (Roosevelt County, 1943) and Saskatchewan (Avonlea, 1909), have also been felt. The regional earthquakes are attributed to major changes in the Precambrian bedrock that occurs along the newly defined Great Lakes Tectonic Zone, which extends east-northeast across several states and into Canada (Craddock, 1972). A recurrence interval of 10 years for a quake with magnitude of 4 or greater has been calculated for western Minnesota (Mooney and Morey, 1981).

3.3 Water Resources

3.3.1 Overview

All of the study areas are located in the central lowland province of the interior plains. This region is characterized by flat rolling plains with very low topographic relief. Surface ponding is common during the rainy season because of the extremely flat topography and the poor drainage capacity of most soils. Little runoff is generated, and water tends to collect in ponds on the surface until it has evaporated or percolated into the groundwater. The fine-grained silts and clays that constitute most of the soils in the area percolate very slowly. Consequently, surface ponds tend to remain throughout most of the rainy season.

Stream and river flows are highly erratic. Flooding is common during the rainy season (April-May), but most streams and rivers have regular periods of low or no flow during the remainder of the year.

Because most surface water bodies are transient, surface water quality is highly variable. Most small streams and rivers are undependable for waste assimilation, irrigation, and municipal supply.

The major surface water quality problems arise from agricultural and stock-raising land use practices. Additional problems result from the fall and spring migrations of birds, wastewater discharges, and mining and construction practices (South Dakota Department of Water and Natural Resources, 1984a; North Dakota Department of Health, 1984; Minnesota Pollution Control Agency, 1984).

Agricultural land use practices increase the levels of pesticides, nutrients, total dissolved solids, and turbidity in surface water bodies. High levels of phosphorus from agricultural runoff are common in most streams. Runoff from stock feedlots results in bacterial contamination, decreased dissolved oxygen concentration, and increased sediment loads.

The large volume of fecal matter deposited in surface water during the fall and spring bird migrations decreases dissolved oxygen concentrations and increases fecal coliforms, un-ionized ammonia, pH, and suspended solids. Nutrient and dissolved oxygen levels are also affected by the wastewater discharges in the region, although this problem has largely been addressed through wastewater treatment requirements. Mining and construction practices result in increased levels of dissolved and suspended solids and turbidity.

As a consequence of the unreliability of surface waters, the majority of the communities rely on groundwater. Groundwater is obtained principally from the Cretaceous bedrock formations, which underlie the entire region, and the Quaternary glacial till formations, which have more localized characteristics.

In general, water from the bedrock is highly mineralized and of poor quality (Downey, 1971, 1973; Downey et al., 1973; Downey and Armstrong, 1977; Jensen, 1967; Jensen and Klausing, 1971; Kelly, 1968; Kelly and Paulson, 1970; Koch, 1975; USGS, 1968, 1970). It is high in total dissolved solids, hardness, sulfate and iron. Water from the glacial drift aquifers exhibits greater variations in quality. The water is generally less mineralized in the shallow aquifers and in areas near recharge zones.

The principal groundwater quality issues are pesticide contamination and increased nutrient levels from agricultural activities, bacteriological contamination from septic tank drain fields and lagoons, hydrocarbon contamination from leaking underground fuel storage tanks, and increased

dissolved solids from oil and gas mining activities. Another issue is contamination of the shallow aquifers by the upward leakage of highly mineralized water from the bedrock aquifers.

No public wastewater collection and treatment facilities exist within most of the study areas. Many population centers in and around the study areas collect sewerage and use a lagoon treatment system. Lagoon facilities exist in Fordville and Galesburg, North Dakota, and in Langford and Pierpont, South Dakota. Most rural households, however, use private, on-lot septic systems. Because low-permeability soils are common, mound systems are sometimes required. (In a mound system, the soil treatment area is built above the ground to overcome limits imposed by the proximity of the water table or bedrock or by soils of high or low permeability.) All on-lot septic systems and community lagoon systems must conform to state and local health department regulations.

All but one of the study areas lie within the drainage basin of the Red River of the North, a tributary to the Nelson River which flows north, emptying into Hudson Bay. The Red River is formed by the confluence of the Ottertail and Bois de Sioux Rivers near Wahpeton, North Dakota. The drainage basin of the Red River consists of the eastern portions of North and South Dakota, the northwestern half of Minnesota, and parts of Ontario, Manitoba, and Saskatchewan, Canada. Flow in the Red River varies greatly, depending on runoff from winter snow accumulation and precipitation. Floods are frequent throughout the basin during the spring because of the flat topography, small stream capacity, and low channel gradient (South Dakota Department of Water and Natural Resources, 1984). Annual average precipitation ranges from 24 inches in the southwest to 17 inches in the northwest, and 60% of the total precipitation falls during the growing season from May through August (Miller and Frink, 1982).

In general, the water quality of the Red River is good. It is the least mineralized river in North Dakota. The main impairments are phosphorus, sulfate, and total dissolved solids (Winter et al., 1984). Red River tributaries tend to be more mineralized and to have greater variations in quality. The low- to no-flow conditions of these smaller tributaries aggravate the dissolved solids concentrations in the water.

The Amherst study area lies within the drainage basin of the James River, which drains the central lowlands of North and South Dakota. This basin is also considered a water-short area because flows are highly erratic, and most small tributaries exhibit long periods of no flow. Floods are also common in this basin during the rainy season because of the flat topography, high groundwater table, and poor local drainage of the soils. Annual average precipitation ranges from 18 inches in the north to 24 inches in the south (South Dakota State Planning Bureau, 1975; USGS, 1962).

The water quality of the James River is generally good. Water quality degradation results from wastewater discharges in the main tributaries south of the study area.

3.3.2 Study Areas

3.3.2.1 Dahlen

3.3.2.1.1 Hydrology

The surface hydrology and topography of this study area are quite varied. The southern sections are covered with numerous transient unnamed streams flowing east to the North Branch of the Turtle River. The Skunk Coulee provides additional drainage. A small unnamed dam, impounds the Skunk Coulee in the south-central section of the study area.

The northern and central sections of the study area are drained by the Middle and South Branches of the Forest River. Near the western edge of the study area, the Matecjek Dam impounds the Middle Branch of the Forest River. The dam was constructed for flood control and recreational purposes. The hundred-year flood zone extends approximately 250 ft on either side of the Middle Branch and 70 ft on either side of the South Branch of the Forest River in this area (HUD, 1980a, 1981b).

The Forest River flows southeast from its headwaters to its confluence with the Red River of the North near Grafton, North Dakota. At Whitman, North Dakota, the Middle Branch has no flow for 4 to 6 months of most years. However, east of the Matecjek Dam, the river flows are regulated and continuous, with periods of low flow occurring during the same 4- to 6-month period. The transient nature of the surface water bodies in this area limits the use of surface water for domestic, stock, or irrigation purposes.

Seasonal high groundwater levels range from 3 to 5 ft below the surface. Glacial drift aquifers are limited. The Fordville and Medford aquifers, 1 mile east of the study area, yield 10-50 gpm (Downey, 1973). Yields of less than 10 gpm can be expected from wells to the glacial till.

No public water supplies exist within the study area. Residents rely on private wells for water use. The town of Michigan, 9 miles southwest, uses both the Pierre aquifer and small glacial deposits for its water supply.

3.3.2.1.2 Water Quality

The water quality of the Middle Branch of the Forest River near Whitman is highly variable (USGS, 1980). Water quality is relatively good during periods of high flow (April-May). In June, the levels of sulfate, total dissolved solids, and manganese are elevated.

3.3.2.2 Goose River

3.3.2.2.1 Hydrology

The eastern sections of the study area are drained by the Goose River, Little Goose River, Spring Creek, Beaver Creek, and numerous unnamed intermittent streams and tributaries. The area is nearly covered with small temporary ponds in the spring. The Little Goose River, Beaver Creek, and Spring Creek are intermittent tributaries to the Goose River. The Logan Center Dam on the Goose River was built in 1936 for recreation and flood control (Schmidt, 1985). The hundred-year flood zone ranges from 250 to 400 ft on either side of the rivers and creeks in this area (HUD, 1980a).

The Goose River is one of the larger tributaries to the Red River of the North. It flows to the southeast toward its confluence with the Red River of the North. Approximately 30 miles southeast of the study area, it has a mean flow of 69 cfs with only short periods of no flow (USGS, 1980). Because the Goose River study area is much closer to the headwaters of the river than the gaging station is, longer periods of no flow probably occur in the study area.

The western half of the study area contains fewer small unnamed streams and temporary ponds. The primary drainage channel is Goose Creek, a transient stream that flows into Beaver Creek, a tributary to the Goose River. The main surface water body is Rugh Lake, a natural water body. Also located in this area are Matson Slough and Horseshoe Lake. These smaller water bodies exhibit regular seasonal variations in volume and area.

Seasonal high groundwater levels range from 3 to 5 ft below the surface. No major glacial drift aquifer formations have been defined in this study area. Yields of less than 10 gpm can be expected from the glacial till (Kelly and Paulson, 1970; Downey, 1973).

No communities with public water supplies lie within the study area. The towns of Northwood, 8 miles east of the study area, and Larimore, 5 miles northeast, use water from the local Elk Valley aquifer (Kelly and Paulson, 1970). The town of McVille, 10 miles west, obtains its water from two wells tapping the local glacial McVille aquifer (Downey, 1973).

3.3.2.2.2 Water Quality

Water quality data for the Goose River, measured approximately 30 miles southeast of the study area, indicate that the water quality of the river is fairly poor. The water is highly mineralized and generally exceeds the federal drinking water standards for total dissolved solids and sulfate (API, 1983). Data are not available on the water quality of the other smaller streams and tributaries in the area.

3.3.2.3 Galesburg

3.3.2.3.1 Hydrology

The surface hydrology and topography of the Galesburg study area are quite varied. The northwestern sections are relatively flat and very poorly drained. Numerous small ephemeral ponds and "prairie potholes" cover the surface during the rainy season. Fullers Lake is a marsh area covering approximately 1 mi^2 along the western edge of the study area. This lake drains into the South Branch of the Goose River, which flows to the north along the western border of the area.

The southern sections of the study area are characterized by slightly hilly topography and fewer small ponds. Water flows from the topographic high in the central portion of the study area into two drainage basins. Water in the west flows to the northwest into Fullers Lake. Water to the east flows to the northeast in small ephemeral streams leading to the Elm River, which flows along the eastern border of the study area. Dam No. 1, constructed for flood control, impounds the Elm River approximately 4 miles northwest of Galesburg. The hundred-year flood zone is from 250 to 500 ft on either side of the Elm River (HUD, 1980b).

The Southern Branch of the Goose River is a relatively large tributary that flows to the north, joining the main stem of the Goose River near Portland in Traill County. The main stem of the river flows throughout most of the year, with infrequent periods of no flow. However, because there are frequent low flows, the principal water source in this area is groundwater. The hundred-year flood zone extends approximately 300 to 400 ft on either side of the Goose River (HUD, 1980).

Seasonal high groundwater levels vary from 3 to 5 ft below the surface. The Galesburg glacial drift formation underlies most of the study area. Yields on the order of 1,000-1,500 gpm can be obtained in the northwestern and southern sections, with lower yields achievable in other areas (Jensen and Klausing, 1971). The Galesburg aquifer, which was formed along the shore of glacial Lake Agassiz, consists of lenticular deposits of sand and gravel interbedded with silt and clay. Recharge is from direct precipitation and infiltration, with discharge to the Elm River and South Branch of the Goose River.

The communities of Clifford and Galesburg use private wells to the Galesburg aquifer as a water source (Jensen and Klausing, 1971). The town of Hope, located approximately six miles west of the study area, obtains its water from two municipal wells to the Galesburg aquifer (Downey and Armstrong, 1977).

3.3.2.3.2 Water Quality

The main stem of the Goose River is highly mineralized and of poor quality for most uses.

The water supply in this area is obtained exclusively from groundwater. Water from the Galesburg aquifer is very hard, but not as mineralized as that from the Dakota. Total dissolved solids, iron, manganese, and sulfate commonly exceed the standards.

3.3.2.4 Blanchard

3.3.2.4.1 Hydrology

The Blanchard study area is drained by the Elm River, which crosses the central sections of the study area. The headwaters for the North and South Branches of the Elm River are in the northern and southern sections. Burke Drainage Ditch No. 15 drains the northern sections of the study area to the North Branch and main stem of the Elm River. There are no major lakes, swamps, or ponds in the vicinity.

The Elm River is tributary to the Red River of the North. Although a major tributary in the area, it has long periods with low or no flow. The hundred-year flood plain extends between 250 and 500 ft on either side of the Elm River and its tributaries (HUD, 1980b).

Seasonal high groundwater levels range from 1 to 3 ft below the surface. No major glacial drift aquifer formations exist within the study area. Yields from the drift are generally less than 10 gpm. The Hillsboro aquifer, which can yield between 50 and 100 gpm, is located approximately 2 miles east of the southeastern section of the study area (Jensen and Klausing, 1971). This aquifer is recharged primarily by direct infiltration of rainfall and snowmelt. The aquifer discharges through seepage along the walls of the Goose and Elm Rivers.

There are no public water supplies within the study area. The town of Blanchard relies on private wells. Hillsboro, approximately 4 miles east, uses three wells tapping the Hillsboro aquifer (Jensen and Klausing, 1971).

3.3.2.4.2 Water Quality

Water from the Hillsboro aquifer, in the vicinity of the study area, is less mineralized than the water from the Dakota (Jensen and Klausing, 1971). The water commonly exceeds federal drinking water standards for iron, total dissolved solids, sulfate, and chloride (API, 1983).

3.3.2.5 Thief River Falls

3.3.2.5.1 Hydrology

No hundred-year flood zones are located in this area (HUD, 1981a and 1983). The area consists of two smaller drainage basins, both of which drain into the Red River of the North. The western sections are part of the Snake River drainage basin. The eastern sections are part of the Red Lake River drainage basin.

The eastern sections of the study area are very poorly drained and covered with numerous swamps and marshes. The center sections are covered by Goose Lake Swamp. Drainage ditches serve the region between these two swampy areas. The ditches and swamps in the eastern and central sections drain to the south, joining the headwaters of the Black River, a tributary to the Red Lake River. The Black River and the drainage ditches that flow into it are classified as state-protected waters. This status requires that a permit be obtained before making any alteration in the course, current, or cross-section of these waters (Minnesota Department of Natural Resources, 1984, 1985). Drainage has been a major problem throughout the Red Lake River watershed (USGS, 1970).

The western half of the study area has better drainage. Several small, transient, unnamed streams channel the water to the west. The small streams drain into the Snake River, which flows parallel to the area's northern border.

The major water source in this area is groundwater. Yields are generally less than 25 gpm. However, most communities in the area have located aquifers that will yield up to several hundred gallons per minute. Seasonal high groundwater levels range from 1 to 3 ft below the surface.

3.3.2.5.2 Water Quality

In general, the surface water is suitable for domestic and agricultural purposes. The community of Thief River Falls, approximately 5 miles east of the area, uses water from the Red Lake River. Red Lake River has good water quality (Minnesota State Department of Health, 1985) and satisfies all federal drinking water standards (API, 1983).

St. Hillaire, a community approximately 5 miles east of the study area, uses three wells that tap the glacial drift acquifer as a municipal water source. Water from these wells is of relatively good quality (Minnesota State Department of Health, 1985), but it exceeds the federal drinking water standard for sulfate (API, 1983).

3.3.2.6 Wheaton N

3.3.2.6.1 Hydrology

This study area is extremely flat and devoid of any major surface water bodies. No hundred-year flood zones have been identified (HUD, 1977). Numerous drainage ditches serve the area and drain surface water to the northeast. Drainage Ditch No. 11 in Sections 29, 32, and 33 of T129N, R34W is classified as a state-protected water course. A permit must be obtained before making any alteration in the course, current, or cross-section of these waters (Minnesota Department of Natural Resources, 1983). The Old Channel of Twelvemile Creek, a tributary of the Mustinka River, parallels the southwestern boundary, about 0.5 mile outside of the study area. Twelvemile Creek is also classified as a state-protected water course. The Mustinka River flows to the southwest and empties into the northern corner of Lake Traverse.

Water for municipal and agricultural uses is obtained entirely from groundwater. Seasonal high groundwater levels range from 7 to 8 ft below the surface. The principal aquifer tapped in the area is the glacial drift. Yields are generally low. Recharge to the glacial till occurs through seepage of precipitation in the morainal area south of Lake Traverse. Groundwater within the drift moves from the morainal area to the northern lake plain area, where it is discharged by flowing wells and by upward seepage in the valley of the Bois de Sioux River (USGS, 1968).

Public supply within the township of Tintah, approximately 5 miles north of the study area, is provided by three wells that tap the till. Public water supply within Wheaton township, approximately 10 miles southwest of the study area, is also provided by three wells that tap the till formations.

3.3.2.6.2 Water Quality

The Wheaton N study area is devoid of major surface water bodies.

The principal ions in the water obtained from the glacial drift formation are calcium, magnesium, and sulfate. The water is very hard and exceeds the federal drinking water standard for iron (API, 1983). In general, the water from the drift is suitable for irrigation and, in some cases, domestic use.

The quality of Wheaton's water supply is relatively good, although it is quite hard (Minnesota State Department of Health, 1985). The water exceeds Federal Drinking Water Standards for iron, manganese, and total dissolved solids (API, 1983).

3.3.2.7 Wheaton SE

3.3.2.7.1 Hydrology

Twelvemile Creek, a tributary to the Mustinka River, provides drainage for this area. The east and west branches and the main stem of the creek meander through most of the study area. All Twelvemile Creek branches have been designated as state-protected water courses. Creek flow moves to the north, where the creek joins with the Mustinka River. Flow is fairly transient, and periods of no flow occur during most years. No hundred-year flood plains are located in this area (HUD, 1977).

Water for municipal and agricultural supplies is provided entirely by groundwater sources. Depth to seasonal high groundwater level ranges from 7 to 8 ft. Yields from the glacial drift are generally less than 10 gpm (USGS, 1968). Recharge occurs as seepage in the morainal area around Lake Traverse. Groundwater within the drift moves to the north, where it is discharged in the Bois de Sioux Valley.

The public water supply for the township of Dumont, approximately 5 miles west, is provided by two wells that tap the drift (Minnesota State Department of Health, 1985).

3.3.2.7.2 Water Quality

Data on the water quality of Twelvemile Creek are not available.

Dumont's water supply is of relatively good quality (Minnesota State Department of Health, 1985). The water is fairly hard and mineralized, and it exceeds federal drinking water standards for total dissolved solids, iron, and manganese (API, 1983).

3.3.2.8 Wheaton SW

3.3.2.8.1 Hydrology

Numerous transient, unnamed streams drain water from the northern half of the study area into Lake Traverse. Drainage in the eastern sections is less effective, and numerous ponds form during the rainy season. The southeastern sections also contain a large swamp and marsh. County Ditch No. 52 provides additional drainage for the south central area, with discharge to Lake Traverse. County Ditch No. 52 and most of the unnamed streams in the area have been designated as state-protected waters. The hundred-year floodplain in this area is located immediately adjacent to Lake Traverse (HUD, 1977).

Lake Traverse, about 1 mile wide and 17 miles long, is the largest water body in the vicinity. The dam at Lake Traverse was constructed in 1937 for flood control purposes. Lake water is not used for water supply.

Groundwater resources are similar to those in the other Wheaton study areas. Seasonal high groundwater levels range from 7 to 8 ft below the surface. Yields from the glacial till formations are generally less than 10 gpm, and most communities do not have a municipal water supply (USGS, 1968). Recharge to the till occurs as seepage from precipitation in the morainal area south of Lake Traverse. Discharge is to the north in the lake plain area of the valley of the Bois de Sioux.

The public water supply for the township of Browns Valley, located approximately 8 miles south, is provided by three municipal supply wells (Minnesota State Department of Health, 1985).

3.3.2.8.2 <u>Water Quality</u>

The water quality of Traverse Lake is good, although high in sulfate (Minnesota Pollution Control Agency, 1986).

The well water supply for Browns Valley is quite hard and fairly mineralized (Minnesota State Department of Health, 1985). The water exceeds federal drinking water standards for iron, manganese, sulfate, and total dissolved solids (API, 1983).

3.3.2.9 <u>Amherst</u>

3.3.2.9.1 <u>Hydrology</u>

This study area has no major surface water features. Pierpont Lake, which is adjacent to the southern end of the study area, is the closest body of water.

Numerous transient, unnamed streams drain the study area with discharge to the west-southwest. Antelope Creek crosses the southern portion of the study area, also flowing to the west, where it converges with Mud Creek, a tributary to the James River. The Crow Creek drainage ditch is the principal drainage channel for the northern half of the study area. Flow moves to the west in Crow Creek drainage ditch and empties into the Renzienhausen Slough, a large wetland located in the northwestern corner of the study area. Flooding is common in the vicinity of the Crow Creek drainage ditch (Koch, 1975).

Groundwater is the principal source of water because of the highly transient nature of most surface water in the area. Depth to seasonal high groundwater levels range from 1 to 3 ft. The principal glacial drift aquifer is the James aquifer, which has narrow channels extending into the northern portion of the study area. The aquifer is composed of

buried outwash deposits consisting of sorted and stratified gravel, sand, and silt. Water in the aquifer occurs under artesian pressure, and the water surface ranges from 2 to 111 ft below the surface. Yields of 500 gpm or more can be obtained from properly constructed wells (Koch, 1975). Recharge to the James aquifer is from groundwater inflow from Brown County and from percolation of precipitation through the overlying sediments.

The town of Amherst obtains water from a well 950 ft deep, that taps the Dakota formation. Langford also obtains water from a municipal well that taps the Dakota. This well is 1,000 ft deep. Three shallow wells, 160-165 ft deep, provide municipal water for the town of Pierpont (South Dakota Department of Water and Natural Resources, 1983).

3.3.2.9.2 Water Quality

The communities of Amherst and Langford obtain their municipal water from the Dakota aquifer. Both supplies exceed federal drinking water standards for total dissolved solids and sulfate (Missouri River Basin Commission, 1980; API, 1983). Amherst also exceeds the standard for chloride, and Langford exceeds the standard for fluoride.

The water in the James aquifer, north of Amherst, is less mineralized and of better quality for domestic and agricultural use. The major constituents of the wells that tap the James aquifer are sodium and bicarbonate (Koch, 1975).

The communities of Andover and Pierpont obtain municipal water from relatively shallow wells that tap the glacial till. These supplies are less mineralized than the supplies that tap the deeper Dakota formation. However, both supplies exceed the federal drinking water standards for total dissolved solids and sulfate (API, 1983).

3.3.2.10 Grand Forks AFB

3.3.2.10.1 Hydrology

The proposed site for the operations center on Grand Forks Air Force Base now contains a paved parking lot, an area with gravel surface, and a large field. The site has no major surface water bodies. The Turtle River, a tributary to the Red River of the North, flows to the northeast along the northern edge of the base.

The base obtains its water from the city of Grand Forks, which takes water from the Red River of the North and the Red Lake River. The combined average daily use for the base and Grand Forks is more than 6 million gallons (Kelly and Paulson, 1970). The base has excess water capacity. An existing 10 inch, asbestos-cement water line is located on G Street approximately 600 ft west of the proposed site. A 4 inch asbestos cement water line is located on 1st Avenue, approximately 600 ft south of the proposed site.

Although no major aquifers exist within the base area, Grand Forks Air Force Base is less than 10 miles east of the Elk Valley aquifer. The Emerado aquifer also underlies the eastern portion of the base (Kelly and Paulson, 1970). This aquifer yields between 250 and 500 gpm in certain areas. However, the water quality is poor, and the water is not satisfactory for municipal use.

3.3.2.10.2 Water Quality

The water of the Red River of the North and of the Red Lake River indicate is of good quality (USGS, 1980; USGS, 1983). The water generally meets all federal and state drinking water standards (API, 1983).

Water from wells tapping the Emerado aquifer is generally of poor quality. It is highly mineralized, the principal ions are sodium and sulfate. The water exceeds federal drinking water standards for fluoride, sulfate, and total dissolved solids (Kelly and Paulson, 1970; Kelly, 1968). The water from wells tapping the Elk Valley aquifer is of relatively good quality.

Base wastewater treatment depends on three sewage lagoons, to which the wastewater is transported by an extensive collection system. An existing 8 inch vitrified clay pipe is located on G Street, approximately 600 ft west of the proposed site. The base is also served by an extensive storm drain collection system. An existing 72-inch reinforced concrete pipe is located on 1st Avenue, approximately 600 ft south of the proposed site.

3.4 Vegetation

3.4.1. Wetland Vegetation

Despite draining for agricultural production, wetlands are abundantly scattered throughout the study area. Numerous streams and temporary waterways meander through the region, through areas slightly depressed below the surrounding land. Besides scattered trees and shrubs (discussed under non wetland vegetation), these stream areas contain emergent herbaceous wetland vegetation such as cattails, sedges, whitetop (a grass), and rushes. The dominant wetland habitat type in most of the area is the prairie pothole. Potholes are small emergent wetlands where wetland vegetation grows in glacial depressions (Tiner, 1984). They are classified as palustrine wetlands because they are dominated by vegetation and have shallow open water, rather than riverine or extensive open water habitat. They may be temporary, drying up in summer, or permanent. Most potholes are about 75 to 200 ft across and, at least in spring, contain open water in the middle. The kinds of vegetation found in pothole wetlands depend on water permanence and depth (Higgins et. al., 1984). A list of common wetland species is given in Table 3-1.

Table 3-1

COMMON HERBACEOUS WETLAND SPECIES OF THE PRAIRIE POTHOLE REGION

WET MEADOW ZONE (Temporarily Flooded)	
Prairie cordgrass	*Spartina pectinata*
Northern reedgrass	*Calamagrostis stricta*
Switchgrass	*Panicum virgatum*
Slender sedges	*Carex sp.*
SHALLOW MARSH ZONE (Seasonally Flooded)	
Whitetop	*Scholochloa festucaea*
Slough sedge	*Carex atherodes*
Marsh smartweed	*Polygonum amphibium*
Giant Burreed	*Sparganium eurycarpum*
DEEP MARSH ZONE (Semi-Permanently Flooded)	
Cattails	*Typha latifolia*
Bulrushes	*Scirpus sp.*

Many thousands of acres of wetlands have been drained to increase land in agricultural production. In the prairie pothole region, about half the wetlands were drained before 1950; in Minnesota, North Dakota and South Dakota, 188,000 acres were converted to farmland in the 1950s and 125,000 acres were drained between 1964 and 1968 (Linder and Hubbard, 1982).

Because of their importance, the U.S. Fish and Wildlife Service (USFWS) owns certain wetlands in this region and administers them as Waterfowl Production Areas (WPAs). In addition, easements are purchased in which the landowner is paid a fee by the USFWS in return for an agreement not to drain, burn, level, or fill wetlands in the area covered by the easement. The Minnesota Department of Natural Resources (MDNR) maintains a list of Protected Waters and Wetlands for each county. Work that would alter these wetlands is not prohibited, but it is severely restricted and is subject to a strict permitting process.

Certain other state-protected areas may also contain wetlands, such as the Wildlife Management Areas (WMAs) administered by the MDNR. These protected areas will be mentioned in the discussion of each individual study area. The relative number of WPAs and easements in an area can generally be taken as an indication of the general importance of wetlands in that area.

3.4.2 Non-wetland Vegetation

The natural vegetation of the project region is grassland, with the exception of the eastern part of the Thief River Falls study area, which extends into the deciduous forest-grassland ecotone (Smith, 1980; Sims and Morey, 1972). Except for the eastern Thief River Falls area, virtually all the land in this region that is not wetlands is under cultivation. Shelter belts of trees and shrubs are often planted between the fields, along section and half-section lines. Shelter belts consist of plains or eastern cottonwoods (*Populus sargentii* or *P. deltoides*), green ash (*Fraxinus pennsylvanica*), and several other native hardwoods. The only naturally occurring trees and shrubs are riparian vegetation found along river and stream bottoms, classified as the cottonwood-willow forest type (Eyre, 1980). Dominant trees are eastern or plains cottonwood, and one or more other cottonwood species. Willows are second in abundance to cottonwoods, and consist of black willow (*Salix nigra*), peachleaf willow, (*S. amygdaloides*), and numerous other willow species. Also present are green ash, boxelder (*Acer negundo*), hackberry (*Celtis occidentalis*), and several shrub species such as alders (*Alnus sp.*) and dogwoods (*Cornus sp*.).

3.4.3. Agricultural Crops

Wheat is the principal crop in most of the project areas. Other major crops are corn, barley, and sunflower (also see Section 3.8.4).

In Brown County, South Dakota, for instance, of which the western part of the Amherst study area is a part, 275,000 acres were planted in wheat in 1985, more than twice as many as in corn (128,000 acres). Barley (78,000 acres) and sunflower (57,000 acres in 1984) were the other dominant crops, and smaller amounts of soybeans, rye, flaxseed and sorghum also grown. The southern part of the Amherst study area is in Day County, where wheat is planted on more acreage (142,000 acres) than the next most commonly planted crops, barley (49,000 acres) and corn (43,000 acres), combined. Sunflower (20,000 acres) and flaxseed (17,000 acres) are also planted on substantial acreage in Day County (Ranek, 1986).

The crops planted in Grand Forks County, North Dakota, which encompasses most of the Dahlen and Goose River study areas, are typical of those grown along the eastern edge of the state. Wheat (216,000 acres), sunflower (80,000 acres), and soybeans (72,000 acres) were the major crops in 1984. Smaller amounts of dry beans, potatoes, barley, sugar beets, oats, and flax were grown (Lipetzky, 1986).

To the west, in Nelson County (western Dahlen and Goose River study areas) and Steele County (most of the Galesburg study area), the dominance of wheat increases, and sugar beets and potatoes are less important. The crop acreage ratios in Traill County (Blanchard study area) are very similar to those in Grand Forks County.

In Traverse County, Minnesota, location of the Wheaton N, Wheaton SE, and Wheaton SW study areas, soybeans (98,000 acres), wheat (91,000), and corn (33,000) were the leading crops in terms of acreage in 1979.

In Pennington County, which is probably more typical of the Thief River Falls study area as a whole than the much larger Polk County, the leading crops in acreage planted in 1985 were wheat (71,000 acres), barley (68,000), sunflower (20,000), soybeans (9,000) and corn (8,000) (Minnesota Department of Agriculture, 1986).

3.4.4 Threatened and Endangered Plant Species

No federally listed threatened or endangered plant species have a range that includes the project areas, but the State of Minnesota maintains a list of legally protected plant species, including endangered, threatened, and special concern species. Some of these species live in the wet prairie-sedge meadows characterizing the eastern portion of the Thief River Falls area, and in the Wheaton SW area on hill prairies along Lake Traverse. These species are discussed in the study area subsections.

3.4.5 Study Areas

3.4.5.1 Dahlen

The northern part of the Dahlen study area is crossed by the Middle Branch of the Forest River about 1.3 to 3 miles north of the Walsh-Grand Forks County line, and by a smaller tributary near the northern edge of the area. The Middle Branch of the river meanders through partially forested palustrine wetlands up to 0.5 mile wide, and constitutes about 2 mi^2 of good waterfowl habitat. The northern tributary is surrounded by emergent wetlands about 200 yards across. Near the western edge of the study area is an impoundment of the Middle Branch of the Forest River that extends about 2 miles east and west and 0.25 miles north and south. The South Branch of the Forest River, an intermittent stream, cuts across the narrow middle of the study area. The southern part of the area is crossed by numerous stream channels and associated wetlands on both sides of Route 32. The terrain is undulating, and there is usually no more than 0.5 to 1 mile of agricultural fields between the stream-associated wetlands. A dam and impoundment about 0.5 miles long exists in the south-central part of the area, on Skunk Coulee. The extreme eastern edge of the area is flatter than the rest, with fewer wetlands. No threatened or endangered plants are known to occur in this area.

3.4.5.2 Goose River

The Goose River study area is primarily farmland. The entire area is interspersed with small ponds and wet areas, at least in spring. Areas of permanent wetland emergent macrophytes, generally along

streambeds, are also numerous, separated by at most 2 miles of agricultural fields.

The USFWS has several areas of interest in the study area including fee-owned WPAs and WPA easements. These lands total approximately 8,000 acres.

The northern part of the study area is slightly rolling country that is crossed by the Goose River and its tributaries. These are generally very small watercourses with associated emergent wetlands about 200 ft across. For about 8 miles to the east of Route 32, the fields are covered with temporary ponds in the spring. Temporary ponds are slightly less common in the eastern portion of this area, but are still present in densities of up to 10 per square mile. In general, never more than a mile separates some form of wetlands, whether a pond or streambed.

Further south, the Goose River study area is also undulating terrain crossed by small watercourses and containing scattered ponds. Rugh Lake, 1 mile long and 0.5 mile wide, is located 2 miles north and 1.3 miles east of the Route 15-Route 32 junction. It is surrounded by other, smaller water bodies. Beaver Creek, a stream with associated wetlands about 150 to 200 yards wide, crosses the area in a northwest to southeast direction about 5 miles east of the road junction. There appear to be no substantial woodlands in either the Dahlen or Goose River study areas. No threatened or endangered plants are known to occur in this area.

3.4.5.3 Galesburg

The Galesburg study area consists primarily of farmland. Two small towns, Clifford and Galesburg, are on the western edge of the area. Aerial photographs taken in May show very extensive small ponds throughout most of the region, sometimes as many as 30 per square mile. These are mostly seasonally flooded emergent wetlands, that would be dry for most of the rest of the year. They remain wet long enough to be important as duck breeding areas, however. More permanent wetland areas include the South Branch of the Goose River in the northwestern part of the study area and the Elm River and its impoundment at Dam No. 1 to the west and northwest of Galesburg. All watercourses in this region, when not modified by man, follow very meandering courses. The South Branch of Goose River has been channelized where it extends into the southern portion of the study area, and an impoundment of the Elm River, about 3.5 miles northwest of the town of Galesburg, is approximately 4 miles long and 0.25 mile wide. The Fullers Lake Wildlife Management Area, managed by the North Dakota Game and Fish Department for the production of waterfowl, is immediately to the west of the Galesburg study area, 7.5 miles west of the town of Galesburg. Hunting is permitted in this area, and trapping by permit.

The USFWS owns several parcels of land in the area that are managed as WPAs, and has purchased easements on numerous parcels; in the latter, the owners retain title to the land, but are prohibited from burning wetland vegetation or filling, draining, or leveling wetlands. The total USFWS land interest in Galesburg is approximately 8,800 acres. Individual WPAs may range from approximately 0.1 mi^2 or less to 0.5 mi^2, and easements from about 0.1 mi^2 to more than 1 mi^2.

The Galesburg study area includes 15 WPAs owned by the USFWS. One of these is at western edge of the area, immediately north of the Fullers Lake State Wildlife Management Area. It is about 1.75 mi^2 in area, and about one-half of it is in the study area. This is an extensive emergent wetland in which the USFWS is currently building islands of raised soil to increase habitat diversity. Another small area is located about 1 mile to the east of these, and three more, of about 0.25 mi^2 each, are in the northeastern part of the study area, near the town of Clifford. The final WPA in the area is in the southern part, about 1 mile southwest of Galesburg. It consists of all natural, grassy emergent wetland vegetation with scattered shrubs. In addition, eight wetland easements have been purchased in the Galesburg study area.

The study area also has many valuable wetlands that are not part of the federal ownership and easement system, including several along the Elm River and its tributaries. No threatened or endangered plants are known to occur in this area.

3.4.5.4 Blanchard

The Blanchard study area has far fewer areas of standing water in the spring; a few such areas are found in the southwestern corner of the study area, where the topography includes a number of low north-south ridges. In the northern part of the study area, just west of the town of Blanchard, the channels of the North and South Branches of the Elm River extend across the study area about 2 to 3 miles apart. These channels meander through wetland areas approximately 200 to 300 yards wide.

The land in the Blanchard study area is noticeably flatter than that at Galesburg, with fewer shelter belts. Other than standing water in roadside ditches, very little wetland is apparent.

No WPAs or easements are in the area, nor in any of the townships of which the area is a part. The nearest wetland easement is in the township of Blanchard, 3.5 miles west of the border of the area. No threatened or endangered plants are known to occur in this area.

3.4.5.5 Thief River Falls

The Thief River Falls study area differs from the other study areas in containing numerous small areas of deciduous woodland in its eastern half. The area is in the transition zone between natural areas of deciduous forest to the east and grassland to the west.

The size of individual tracts of woodland is extremely varied, but 3 or 4 sections in the western portion of the study area are approximately 50% wooded, and several others may be as much as 25% wooded.

Several large palustrine emergent wetlands of 50 to 100 acres are interspersed with the wooded areas in the western part of the area. A large, elongated wetland, Goose Lake Swamp, extends in a north-south direction down the middle of the area. It is more than 7 miles long by 0.3 to 0.5 mile wide. Several other wetlands exist to the west, including two of approximately 0.5 mi^2 each just to the west of the Polk-Pennington county line. Both wetlands and woodlands grow scarcer to the west, although only a few sections,along the extreme northern and western edges of the area, and virtually devoid of either of these habitat types.

The USFWS does not own land or hold easements in the study area (Welford, 1986), but the MDNR Natural Heritage Program maintains a list of natural plant communities that have been little modified by man's activities and ranks them according to their relative rarity and endangerment. One such area is a natural prairie, the Belgium Prairie WMA, just outside the study area, in the Township of Belgium, 0.5 mile south of the study area border. This is a wet blacksoil prairie, which is threatened within the state. It contains one state special concern species: the white lady's slipper (*Cypripedium candidum*).

No plant species of special state concern are known to occur within the Thief River Falls study area, although white lady's slipper, sticky false asphodel (a lily, *Tofieldia glutinosa*) marsh arrow grass (*Triglochin palustris*), and *Carex scirpiformis* (a sedge) are known from locations just outside the area (Minnesota Natural Heritage Program, 1986).

One wildlife management area administered by the MDNR--the Pembina WMA--lies in the central portion of study area. The Pembina WMA includes parts of Goose Lake Swamp and is an important staging area for migrating waterfowl.

There are nine protected wetlands in the Thief River Falls study area. These include Goose Lake, in the center of the area, three large wetlands to the west of 0.2 to 0.3 mi^2 each, and five areas in the eastern part of the study area that range from less than 0.1 to 0.3 mi^2. A protected watercourse, the Black River, runs north to south about 1 to 2 miles east of the Goose Lake wetland.

3.4.5.6 Wheaton

This study area is almost entirely agricultural fields. The only trees are small stands around houses, averaging one or two stands per square mile. There are no permanent wetlands within the site because the only watercourses are intermittently filled drainage ditches. No plant species of special state concern are known to occur in this area, nor are any federal endangered or threatened species found.

3.4.5.7 Wheaton SE

The Weaton SE study area is flat. It has few trees other than stands around farmhouses, averaging approximately one stand per square mile. The chief topographic and vegetational feature of the area is an intermittent stream, Twelvemile Creek, and two of its tributaries. These state-protected waters follow a meandering course across the area. Aerial photos taken during spring reveal an average of approximately one temporary pond per square mile.

There are at least two tracts of native prairie about 2 miles north of the northern end of the study area. No specific state or federal areas of concern exists in the area itself.

3.4.5.8 Wheaton SW

This study area is relatively flat agricultural land, with few trees except small stands around farmhouses. The area has numerous prairie pothole emergent wetlands. In spring, the number of these wetlands may average 10 per square mile, and individual sections may have 20 or more. Small streams in the area have often been channelized, which somewhat diminishes stream-associated wetland areas.

Hill prairies along Lake Traverse in the northwestern part of the study area contain state special concern or endangered plant species. These include Missouri milk vetch (*Astragalus missouriensis*), a species of special concern found on dry prairie bluffs in the township of Wall (T. 126 N., R. 57 W., Section 7) overlooking Lake Traverse, and Wolf's spike rush (*Eleocharis wolfii*), a species endangered within the state and found near Lake Traverse.

Traverse County has one WPA owned by the USFWS, and five wetland easement areas. These are located in the eastern part of the site, except for one easement area in the extreme southwestern section. Two state-protected wetlands are closely associated with the federal WPA.

Immediately south and west of the study area, from 2 to 5 miles from its border, is a heavy concentration of federal and state protected wetlands, including 10 federal WPAs and 47 state-protected wetlands and basins.

3.4.5.9 Amherst

This study area is generally agricultural and is crossed by several intermittent streams. The major streams include Crow Creek (partially ditched) and Antelope Creek, which are tributaries to Mud Creek and which flow to the James River. These creeks, except for low-lying emergent wetlands, are dry or without flow during most late summers. They are characterized by a generally poorly defined channel with numerous pools and meanders. Woody riparian vegetation is generally limited to scattered willows although there is also some green ash and American elm (Keenlyne, 1986).

Tree breaks or shelter belts are more numerous in the northern than in the southern part of the area. They often extend entirely across a section, usually in an east-west direction.

Renzienhausen Slough is an extensive wetland in the northwestern corner of the Amherst study area, covering more than a square mile. It is a Game Production Area managed by the South Dakota Department of Game, Fish, and Parks. In addition to Renzienhausen Slough, the following potentially significant resource areas have been identified by the USFWS (Keenlyne, 1986):

- Crow Creek--northern part of study area. Unditched stream areas and associated wetlands provide good wildlife habitat.

- North central part of area--medium to high concentration of shelter belts. Most wetlands in this area have been drained.

- Southern part of area - medium to high concentration of intermittent streams; medium to high waterfowl use in the following locations: T. 124 N., R. 59 W., Sections 7, 8, 9, 10 14, 15, 16, and 17. Adjacent to these sections, just outside the southeast boundary of the study area is an emergent wetland with an area of approximately 0.5 mi^2.

- U.S. Fish and Wildlife Services easements--In T. 123 N., R. 59 W., Section 12, near the extreme southern part of the study area.

3.4.5.10 Grand Forks AFB

The intended site of the operations center consists of an existing paved parking lot. Beyond the paved parking lot to the east is a graveled area and beyond that is an open field approximately 5 acres in size. The field is generally dry; however, wet areas occur during the rainy season because of poor drainage. Vegetation in the field consists of 1- to 2-ft tall grasses providing limited wildlife habitat. The field is surrounded by industrial development on its north, south, and west sides. On the eastern border of the site is a stand of trees serving as a shelter belt. No plant species of special state concern are known to occur in this area, nor are any federal endangered or threatened species found.

3.5 Wildlife

3.5.1 Mammals

Whitetail deer (Odocoileus virginianus) is the most common large mammal in the area, as it is throughout most of the United States. The local subspecies, Dakota deer (O.v. dacotensis), ranges from western Minnesota westward to central Montana and north into Canada (Halls, 1978). The abundance of deer may be somewhat limited in this area by the availability of browse (leaves, stems, and buds of woody plants) and of winter cover. Deer eat forbs (herbs other than grass) heavily in the spring, when they are succulent and green, and they eat agricultural crops such as soybeans that grow close to forest habitat. Deer do not generally migrate; rather they move about in search of food on a home range, which in Minnesota varies from 175 to 470 acres in size (Roughstad and Tester, 1969). There may be a fall movement to a winter range in response to snow depth and cover. Deer seek shelter in the winter and concentrate in "yards" (which are not defined by cover type, but simply as any area where deer gather for the winter) that may hold from a few to hundreds of deer. During this period, from December to April, deer generally remain within 0.25 miles of coniferous cover if it is available. Coniferous cover is scarce in this region.

Moose (Alces alces) are common in northern latitudes around the world. The southern edge of their range is in the northernmost parts of the project region (i.e., the CRS search area), and moose consequently are found only in isolated areas. The subspecies found in this region is the northwestern moose (A. a. andersoni). Moose most often use early successional woody browse as food, but they adapt to a variety of available forage, including forbs and aquatic vegetation (Franzmann, 1978; Whitaker, 1980).

Moose are essentially solitary and do not normally travel long distances, having a restricted home range of 3 to 6 mi^2. The mating season for moose is from September through November, and calves are born in late May and June. The pregnant female seeks seclusion for the birth of her calf, but does not migrate to any specific calving area.

Moose are good swimmers, and are often found near water. Besides eating the willow and aquatic vegetation found there, they may nearly submerge themselves or roll in a wallow to acquire a coat of mud as protection against flies and mosquitos.

Elk (Cervus elaphus) once ranged throughout most of the United States, but are now confined mainly to the Rocky Mountains and Pacific Coast regions. Available maps of elk distribution do not include the study areas. Boyd (1978) indicates that their closest occurrence is at least 200 miles north, near Lake Winnipeg in Canada. Whitaker (1980) shows their range as extending south to the U.S.-Canadian border.

Officials of the USFWS and the North Dakota Game and Fish Department (NDGFD) have stated that there are few, if any, elk in the North Dakota study areas, except an occasional stray in the north (Collins, 1986; Sambor, 1986). Farmers in the Blanchard area, however, have reported seeing several elk (Manson, 1986).

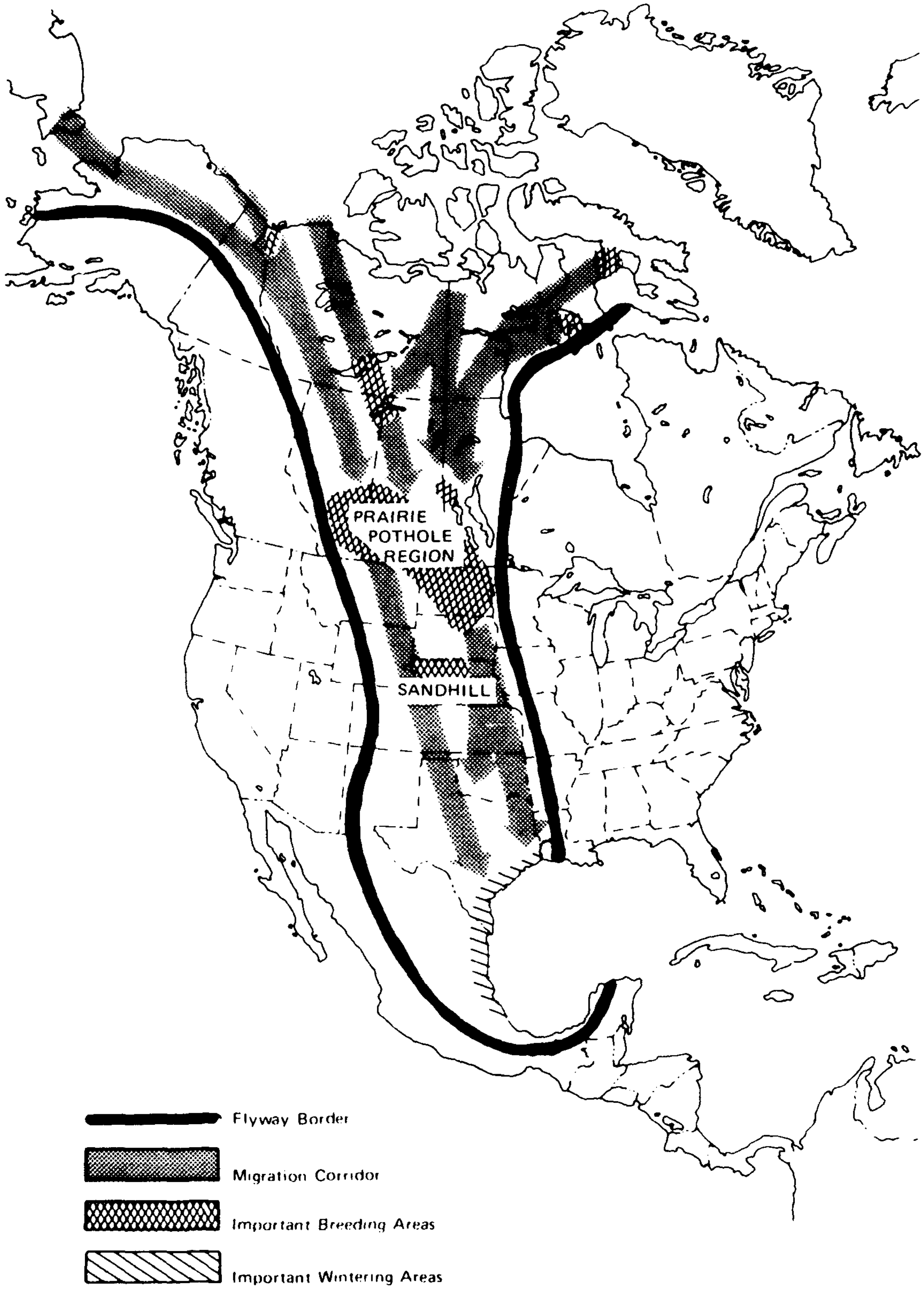
The project region is within the range of at least 24 species of smaller mammals, including several squirrels, gophers, and mice (Whitaker, 1980). The muskrat (Ondatra zibethicus) is a common inhabitant of permanent water in wetlands. Other wetland-dependent mammals include beaver (Castor canadenis) and mink (Mustela vison). The eastern cottontail and white-tailed jack rabbit are both common in the area. The striped skunk (Mephitis mephitis), raccoon (Procyon lotor), and several foxes are common predators on duck eggs in this region, and are sometimes the cause of low nesting success. Foxes in this region include the red fox (Vulpes vulpes), swift fox (Vulpes velox), and gray fox (Urocyon cinereoargenteus). Other predators whose range may include this area are the coyote (Canis latrans),the badger (taxidea taxus), the least weasel (Mustela nivalis), and the long-tailed weasel (Mustela frenata). Several mammals are valuable furbearers. According to the NDGFD, the species most often trapped in eastern North Dakota are muskrat, mink, fox, and raccoon.

3.5.2 Birds

The study areas include some very important habitats for both local and migratory bird populations, primarily because of the extensive wetlands in the project region. Migratory birds pass through this region in spring and fall traveling the Central Flyway, a major north-south artery for migration in North America (See Figure 3-1). The birds use the wetlands as feeding and resting sites en route to their northern summer breeding grounds, or southern wintering areas. For some migratory species, this region is the northern terminus of their migratory route and serves as their breeding ground. Local, nonmigratory birds also use the wetlands for feeding and breeding.

3.5.2.1 Central Flyway

The Central Flyway consists of two major components (see Figure 3-1): breeding grounds to the north, and wintering grounds to the south. The breeding grounds extend from Nebraska "sandhills" in northern Nebraska to the Siberian tundra. Principal wintering areas are located in marshes and open water in the southern United States, the Pecos and Rio Grande Rivers in New Mexico, and Mexico's Central Highlands (Bellrose and Heister, 1985). These birds travel the Central Flyway twice a year, migrating north in spring to breed and south in fall to wintering areas. Several bird populations (numbering in the hundreds of thousands) migrate through the Central Flyway. Migrants include shorebirds (sandpipers, curlews, godwits and plovers), ducks (mallards, pintails, widgeon, gadwall, teals and several diving ducks), geese (snow geese and Canada geese), cranes (sandhill and whooping), and swans.



SOURCE Bellrose and Heister, 1985

FIGURE 3-1 CENTRAL FLYWAY

Most of the ducks in the Central Flyway enter from the prairie pothole district of the Northern Great Plains, where they breed during the summer and then migrate south. Mallards (Anas platyrhynchus) predominate, numbering about 2 million. Pintails (Anas acuta) reach about 1.5 million. Sizable populations of widgeon (Anas americana), gadwall (Anas strepera), blue-winged teal (Anas discors), and green-winged teal (Anas crecca) also migrate along several corridors within the Central Flyway (Bellrose and Heister, 1985).

Canada geese (Banta canadensis) also travel the flyway. Populations of these geese head south from nesting areas lying between Canada's Mackenzie River and the Queen Maud Gulf. Others enter the eastern part of the flyway from the Baffin and Southhampton Islands, north of Hudson Bay. They form two distinct groups: the "tallgrass prairie population" of about 150,000 geese, and the "shortgrass prairie population" of about 120,000 geese.

3.5.2.2 Breeding Grounds for Migrants

Many species of migratory ducks breed in the prairie wetlands. These birds migrate to this region in spring and breed through the summer. In a study on waterfowl productivity in the prairie pothole region, Duebbirt (1981) found 976 pairs of breeding birds on 0.42 mi^2 of North Dakota wetlands. These pairs represented 35 species of birds dependent on wetland habitat for nesting. He also found 35 bird species nesting in associated uplands. Prairie marshes are only 10% of the continent's waterfowl breeding habitat by area, yet they contribute an average of 50% of the duck crop. The single most important factor regulating the production of mallards and other dabbling ducks (ducks that nest on land) is the abundance of ponds in the prairie (Linder and Hubbard, 1982).

Diving ducks, unlike dabbling ducks, nest over water. Stoudt (1971) reported that diving ducks such as canvasbacks (Aythya valisineria) had high breeding success when water levels were comparatively high and stable. Diving ducks, including redheads (Aythya americana) and ruddy ducks (Oxyura jamaicensis), inhabit the more permanent potholes that contain abundant emergent cover. The majority (75%) of breeding diving ducks in North Dakota occupy semi-permanent wetlands, while the majority of the dabbling ducks occupy seasonal wetlands. Diving ducks normally spend the greater part of their time on relatively deep open-water areas, while dabblers inhabit the shallow peripheral areas. Brewster et al. (1976) estimated the breeding population of diving ducks in eastern South Dakota at 32,600 pairs, and Stewart and Kantrud (1974) estimated the breeding poplation of diving ducks in North Dakota at 198,000 pairs.

3.5.2.3 Food Source for Migrants

The wetlands of the prairie pothole region within the project region provide food and rest areas for many species of migrating birds. These migratory birds include both those migrating through the region

(such as geese) and those migrating to the region to breed (such as mallards). Migrating birds depend on obtaining food during their flight north in the spring to provide energy for reproduction. Dabbling ducks, such as mallards and gadwalls, feed on aquatic plants, seeds, grass, small aquatic animals, and insects. The diving ducks, such as the teals, feed on small aquatic animals and plants. Geese feed on grasses, seeds, and aquatic plants. The shore birds generally feed on insects and some vegetable matter during migration, and cranes are omnivorous. Most of the migratory birds obtain their food from the productive wetlands in this region, which contain abundant plant and animal life. Grazers such as geese also feed on grains in the large farm fields.

According to Bellrose (1979), waterfowl such as the dabbling and diving ducks in the project region use a variety of wetland types during their annual cycle, ranging from shallow intermittent ponds to permanent standing water. Early in spring, when the birds first arrive in the breeding areas from the southern wintering grounds, waterfowl require high quality foods to maintain high levels of egg production. A number of studies in the prairie pothole region have shown that this high-quality food is found in shallow wetlands (Linder and Hubbard, 1982). The surface water in these temporary and seasonal basins becomes warm early in spring. They retain water long enough to develop an invertebrate population that provides a rich source of food protein during the early nesting season, especially for dabbling and diving ducks. As these wetlands dry, ducks, such as blue-winged teal, shift their feeding habitats to semipermanent wetlands (basins that usually hold water over most of the summer) and lakes where adult aquatic insects (on which they can feed) are beginning to emerge (Linder and Hubbard, 1982). Many waterfowl move to specific types of wetlands for moulting. These areas must provide food, cover, and isolation and protection from predators during the birds' flightless period. Extensive areas of shallow water with a rich food source and good cover constitute the optimal moulting area.

3.5.2.4 Local Bird Populations

Many nonmigratory birds also inhabit the prairie wetlands. These wetlands provide food and nesting sites for local bird populations. Weller and Spatcher (1965) and Weller and Fredrickson (1974) found different local bird species associated with different habitat resources in prairie wetlands. For example, red-winged blackbirds (*Agelaius phoeniceus*) use shoreward vegetation, whereas yellow-headed blackbirds (*Xanthocephalus xanthocephalus*) use robust emergent vegetation. Coots (*Fulica americana*) and pied-bill grebes (*Podilymbus podiceps*) both nest over water in medium-dense cover with adjacent water openings. The marsh habitat was divided into at least three vertical strata for nest sites: (1) at water level without emergent vegetation (terns and grebes) and at water level with nests built in emergents (rails and ducks); (2) above the water level, but in short and weak vegetation (wrens and red-winged blackbirds); and (3) above the water level in tall cattail (*Typha sp.*) and similar robust emergents (yellow-headed blackbirds).

3.5.3 Other Species

3.5.3.1 Amphibians and Reptiles

The number of amphibians and reptiles living in this region is very small, probably because of the harsh climate, the extreme range of temperature, and the lack of permanent water and wooded habitat. The ranges of two turtles, five snakes, two salamanders, and eight frogs and toads include the project region (Conant, 1975; Behler and King, 1979). The turtles are the snapping turtle and the western painted turtle; they live only near permanent water. All amphibians need water for at least part of their life cycle. The snakes whose range includes this region, with the exception of the western hognose snake, are only found near water or in moist areas (Conant, 1975; Behler and King, 1979). The presence of nearly all of the expected amphibian and reptile species is therefore dependent on the presence of water.

3.5.3.2 Fish

The primary game fish found in the rivers of the North Dakota study areas is the northern pike (*Esox lucius*), which ascends these streams from the Red River of the North. Rock bass (*Ambloplites rupestris*), suckers (*Catastomus spp.*), and bullheads (*Ictalurus spp.*) are also found in these rivers, which include the Forest River in the Dahlen study area, the Goose River in the Goose River study area, and the Elm River in the Galesburg and Blanchard study areas.

The reservoir at Matecjek Dam on the Forest River in the northern part of the Dahlen area is stocked by the North Dakota Game and Fish Department with northern pike, walleye (*Stizostedion vitreum*), black crappie (*Pomoxi nigromaculatus*), and bluegill (*Lepomis macrochirus*). These species may occasionaly spill over the dam into the river system (Pich, 1986).

The Thief River Falls study area does not contain any significant fisheries resources (Ashe, 1986). The only significant fish populations at any of the southern Minnesota study areas are in Lake Traverse, at the western edge of the Wheaton SW study area. This lake is stocked with northern pike, walleye, largemouth bass (*Micropterus salmoides*), and bluegills, and also contains a natural population of black crappie (Larson, 1986). The Amherst site contains virtually no fisheries resources (Hanson, 1986).

3.5.4 Threatened or Endangered Animal Species

Animals on the federal threatened and endangered species list that may occur within the study areas are listed in Table 3-2.

Table 3-2

THREATENED OR ENDANGERED ANIMAL SPECIES

Common Name	Scientific Name	Classification	Distribution
Gray wolf	Canis lupus	Threatened	Peripheral range
Bald eagle	Haliaeetus leucocephalus	Threatened	Migratory range
Peregrine falcon	Falco peregrinus	Endangered	Migratory range
Piping plover	Charadrius melodus	Endangered	Migratory range, breeding
Whooping crane	Grus americana	Endangered	Migratory range

Source: Welford, 1986; Keenlyne, 1986.

The range of the gray wolf, which extends to eastern Pennington and Polk Counties, is closest to the Thief River Falls study area. However, the wolf probably does not occur in this area (Welford, 1986). Among the endangered birds are two raptors, the bald eagle (Haliaeetus leucocephalus) and the peregrine falcon (Falco peregrinus). Both of these species migrate through the project region in spring and fall. The endangered whooping crane (Grus americana) also migrates through the Central Flyway in spring and fall. This species breeds in Alberta, Canada and migrates through the Great Plains to coastal Texas. It inhabits prairie pools and marshes. The piping plover (Charadrius melodus), also endangered, is known to breed in the wetlands of the project region during summer.

South Dakota and Minnesota maintain state lists of threatened and endangered species, some of which are not on the Federal threatened and endangered species list. Inclusion on these lists indicates that the species are considered to be threatened or endangered within a state, even though the USFWS does not consider them to be threatened or endangered throughout their range.

Among the state-listed species that have been identified by the Minnesota Natural Heritage Program as occurring on or near the study areas are seven species of birds. Two of these--the state-endangered chestnut-collared longspur (Calcarius ornatus) and the special-concern species marbled godwit (Limora fedoa)--have been observed in Miller Prairie West, a 375 acre area of natural prairie 2 miles north of the Wheaton SE study area. Ten occurrences of five bird species listed as of special concern in Minnesota have been reported in the Thief River Falls study area, in or near the Pembina Wildlife Management Area or the associated Goose Lake Swamp in the south-central part of the study area.

These species include the sharp-tailed sparrow (Ammospiza caudacuta), Wilson's phalarope (Phalaropus tricolor), the greater prairie chicken (Tympanuchus cupido), the yellow rail (Coturnicops noveboracensis), and the greater sandhill crane (Grus canadensis).

The range of two bird species listed as threatened in South Dakota may include the Amherst project area: the osprey (Pandian habiaetus) and the buff-breasted sandpiper (Tryngites subruficollis). The osprey is found only near large bodies of water, and the buff-breasted sandpiper occurs in short-grass habitats.

A mammal not on the federal list that may occur in the Amherst area is the threatened northern swift fox (Vulpes velox hebes).

Lack of permanent water in the Amherst study area would probably prevent the occurrence of any of the threatened or endangered fish species there.

One South Dakota threatened reptile, the northern red-bellied snake (Storeria occipitomaculata), has a range that may include the study area. However, because this snake is found primarily in hilly woodland or sphagnum bogs, it is doubtful that it actually occurs in the Amherst or any other study area.

3.5.5 Study Areas

3.5.5.1 Dahlen

This study area provides relatively good habitat for mammals because of its shelter belts and the wooded areas along the Middle Branch of the Forest River, the South Branch of the Forest River, and Skunk Coulee, an intermittent stream in the southern part of the study area. A few moose and elk may occur at Dahlen, although their numbers are so small that they are not considered significant species in eastern North Dakota by the North Dakota Game and Fish Department (Sambor, 1986). The presence of numerous palustrine/emergent wetlands at the Dahlen study area increases the area's value to mammals. Wetlands are important to populations of white-tailed deer, and are necessary to muskrat (Linder and Hubbard, 1982). These wetlands also provide feeding and resting areas for both local and migratory bird populations.

3.5.5.2 Goose River

This area has few shelter belts and other wooded areas. Most surround farmhouses. The large number of wetlands in the area make it attractive to wetland-dependent mammals such as muskrat and mink, however, and may increase the deer population by providing food and water. The wetlands in this area also provide feeding and resting areas for migratory and local bird populations. A federal Waterfowl Production Area is located in the southwest corner of this study area, just south of Route 15.

3.5.5.3 Galesburg

The Galesburg study area is approximately equal to the Dahlen and Goose River study areas as mammal and waterfowl habitat because it contains moderately dense shelter belts and numerous emergent wetlands. This area contains five federal Waterfowl Production Areas. The Fullers Lake Wildlife Management Area, on the western edge of the site, and the federally owned Fullers Lake WPAs immediately to the north of it are important mammal and bird habitats. Trapping is allowed by permit in the state-owned Wildlife Management Area. A small number of moose and perhaps elk stay in the vicinity of the Fullers Lake area. These animals move within a range of several miles. The moose move between Fullers Lake and Hope, to the north, and Erie to the southwest, and the elk generally move between Fullers Lake, Hope, and Galesburg, covering much of the Galesburg study area (Manson, 1986).

3.5.5.4 Blanchard

The Blanchard study area is nearly all agricultural fields, and because of the lack of variety in the habitat provided by shelterbelts and wetlands, it is relatively poor as wildlife habitat. White-tailed deer undoubtedly occur in small number in the area, but they would be more attracted to the varied terrain to the west. No other large mammals are known to occur in this area. Bird habitat is limited because of the lack of wetlands. Birds do, however, feed on grain in the agricultural fields.

The USFWS has found no locations areas of significant value at this study area (Collins, 1986).

3.5.5.5 Thief River Falls

This study area includes good habitats for large mammals, especially in the Pembina WMA in the center and the wooded areas in the eastern part of the site. Deer and moose are present in significant numbers in the area (Kurcinka, 1986; Welford, 1986). Deer winter in timber stands of greater than approximately 80 acres that are scattered throughout the area to the east of the WMA, and they sometimes feed in corn fields, depending on the supply of corn. The moose population in the area is considered to be high, and 30 to 40 moose are known to inhabit an area within a 2 to 3 mile radius of the WMA (Kurcinka, 1986). The varied, partly wooded habitat of this area also makes it more suitable for smaller mammals such as foxes, racoons, and skunks.

Several bird species that are found in or near the Thief River falls study area have been listed by the Minnesota Natural Heritage Program as threatened, endangered or of special concern. These species include small birds such as the yellow rail (Coturnicops noveboracensis), Wilson's phalarope (Phalaropus tricolor), and the sharp-tailed sparrow (Ammospiza caudacuta). According to the Minnesota Department of Natural

Resources, these birds have been known to nest in the area and have lower level flight characteristics than waterfowl. The greater sandhill crane (Grus canadensis) and the prairie chicken (Tympanuchus cupido) also breed within the area. Nearly all these species are found in the southern two-thirds of the study area, the same portion of the site that has the best habitat for waterfowl, deer, moose, and other wildlife species.

3.5.5.6 Wheaton N

Deer probably occur in small numbers in the area, but would be attracted to other areas with greater cover.

During wet periods the area may attract many waterfowl, such as mallards, Canada geese, and sandpipers, during migration periods. The site has no known state-listed species or communities of special concern. No state wildlife management areas, federal WPAs, or federal wetland easement areas are located within this study area.

3.5.5.7 Wheaton SE

This study area has few trees and would not be especially attractive to mammals. A few mammals such as racoon and muskrat may be attracted to Twelvemile Creek and its associated wetlands and scattered wooded areas. The area is subject to flooding during wet periods and therefore attracts some waterfowl during migration periods. One small impoundment has been constructed on the western edge of the study area. According to the MDNR, this pond is heavily used by resident Canada geese and also attracts geese during migration periods. Both resident and migrating geese feed in fields near the pond. Also, according to the MDNR, a state-endangered bird species, the chestnut-collard longspur (Calcarius ornatus), has been observed in the Miller Prairie West (T. 127 N., R. 45 W., Section 33, N 1/2), an area of natural prairie about 2.5 miles north of the northern edge of the study area. The state-special-concern marbled godwit (Limosa fedoa) has also been observed in Miller Prairie West and may breed there (Minnesota Natural Heritage Program, 1986).

3.5.5.8 Wheaton SW

This study area also has very few trees, which limits its suitability as habitat for large mammals. The numerous wetlands may support water-dependent mammals and birds. According to the MDNR, a substantial number of waterfowl and other migrant birds use this corridor (Red River-Lake Traverse-Big Stone Lake-Minnesota River) and fly back and forth between Mud and Traverse Lakes and the study area and the potholes to the south. One federal Waterfowl Production Area is located within this study area, and several WPA's are located from 1 to 5 miles to the south and west of the area.

3.5.5.9 Amherst

In the north-central and northern part of this study area, a medium to high density of shelterbelts provides the cover and browse needed by white-tailed deer and smaller mammals. In the northern part of the study area, Renzienhausen Slough and Crow Creek provide wetlands, and consequently are good wildlife habitat. Good wetland habitat is also provided by Antelope Creek and several intermittent streams in the southern part of the study area. Several intermittent prairie streams including Antelope Creek and Mud Creek, provide good waterfowl breeding habitat. According to the USFWS migratory birds do not appear to be a major concern. Migratory pathways occur just to the west (James River) and to the east (Coteau des Prairies) of the study area. Local bird populations, however, do use the intermittent streams. The peregrine falcon (*Falco peregrinus*), federally listed as endangered, and the bald eagle (*Haliaeetus leucocephalus*), listed as threatened, may occur in the project area.

3.5.5.10 Grand Forks AFB

The operations center site provides limited wildlife habitat because of the lack of habitat variety and the proximity of developed areas. A few local bird species as well as some small mammals probably feed in the surrounding fields.

3.6 Air Quality

3.6.1 Climate

All the study areas typically experience a continental climate marked by very wide temperature variations (NOAA, 1982). The absence of large water bodies in the project region also contributes to rapid fluctuations in temperature. Temperatures may range from above 100^{o}F in summer to -50^{o}F in winter. Annual mean temperatures are about 36^{o} in the extreme north to 43^{o} in the southern areas. In the northern areas, subzero temperatures can occur from October to April. Freezing temperatures have occurred as late as the first part of June and as early as the first few days of September; however, the last freeze in spring averages from early May in the south to late May in the northern areas. Generally, summers are characterized by hot winds and periods of prolonged high temperature, but nights are cool. Winters are long and cold.

Mean annual precipitation is about 19 inches; one-half to three-quarters of this total falls during the crop growing season between April and September. Precipitation reaches a maximum in June and is often the result of thunderstorms that produce heavy rainfalls over a short time. Hailstorms are most frequent in midsummer, and lightning does its worst damage in late summer. Occasionally, snow fall is heavy

in winter, and the snow can accumulate to considerable depths. Blizzards, which normally occur once or twice a winter, produce gale-force winds that fill the air with fine, wind-driven snow. Rail and highway traffic may be stalled for several days, and widespread loss of livestock may result from these severe storms.

Serious flooding has been caused by both heavy rainfall and rapid melting of heavy snow pack. The latter condition can be aggravated by ice jams.

Drought effects usually become evident soon after the rainfall drops below normal. Because all the study areas are in a semiarid region, crop returns are very sensitive to rainfall. Long hours of sunshine make it possible to grow a variety of crops in what appears to be a comparatively short growing season.

Although thunderstorms cause more damage to property, tornadoes occur during the early summer months and are far more apt to strike in the southern study areas. The average number of tornadoes reported is 15 per year, but because of widely dispersed population centers, loss of life has been small.

All areas have a considerable amount of fair weather with excellent visibility. Winds are normally southerly in summer and northerly in winter. The annual average wind speed is about 11 mph.

3.6.2 Air Quality Conditions

3.6.2.1 North Dakota

Each of the study areas is a sparsely populated area of intensive farming. Because of the low concentration of industrial plants, this region meets Environmental Protection Agency (EPA) standards for all air pollutant emissions (McDonald, 1986).

Sizable industrial air pollutant sources are located as far away as East Grand Forks, Minnesota (Lancaster, 1986). Among them are a sugar beet factory and several potato processing plants. Another sugar beet processing factory operated during the winter months is also located in Hillsboro, North Dakota, 6 miles east of the Blanchard study area. These processing plants, which use fuel oil or natural gas, are not large enough to require permits or other regulation. Because of the few sources, extensive air quality monitoring data and emission inventories have not been undertaken for this part of the state.

3.6.3.2 Minnesota

The three study areas near Wheaton and the study area west of Thief River Falls are all in rural areas. No major emission source is closer than approximately 30 miles, and none of these sources contributes appreciably to the degradation of ambient air quality (Lancaster, 1986). The closest major emission source is Big Stone Power Plant, a 420-MW,

lignite-fired power plant, located just over 30 miles south of the Wheaton SW study area between Milbank and Big Stone City, South Dakota (South Dakota Department of Water and Natural Resources, 1984b, 1986). It also is a background monitoring station for sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and total suspended particulates (TSP). Even though this plant is South Dakota's largest source of SO_2, at 27,000 tons per year (t/y), concentrations measured at this station have been low. The highest 24-hour SO_2 concentration for 1985 was less than 5 $\mu g/m^3$, as was the arithmetic mean. The highest 24-hour SO_2 concentration ever recorded was 10.1 $\mu g/m^3$ in June 1980. No South Dakota site has had any problem meeting the state NO_2 standards. Other small local sources such as seasonal agricultural burning and the burning of coal or fuel oil at sugar beet factories outside the study area contribute little to air quality degradation.

Except for the greater Minneapolis-St. Paul area, no limits are set in the state's Air Pollution Control Rules on emissions from internal combustion engine power sources. However, any operation that emits between 20 and 100 t/y of any one major pollutant must be issued a minor permit. A major permit is issued to those industrial operations that emit more than 100 t/y of any one pollutant.

Most roads in the Minnesota study areas have light traffic volume. Therefore, TSP concentrations are usually caused primarily by farming activities (Chamberlain, 1986).

3.6.3.3 South Dakota

Except for the town of Amherst, virtually all of the Amherst study area consists of prairies, wheat farms, and ranches. For the most common pollutant emissions, agricultural operations contribute only slightly to the degradation of local air quality (Wetstein, 1986). No local sources other than grain elevators exist in the study area. Outside the study area, the only significant air pollution sources are two industrial plants in Aberdeen, more than 30 miles away. South Dakota defines "significant" as an emission rate equalling or exceeding any of the following: carbon monoxide--100 t/y; nitrogen oxides--40 t/y; sulfur dioxide--40 t/y; particulate matter--25 t/y; ozone--40 t/y of volatile organic compounds; lead--0.5 t/y.

Locally, the greatest air quality problem is airborne dust generated by agricultural operations and vehicle use. Measurements of TSP taken weekly in Aberdeen, South Dakota, in 1984, show a geometric mean concentration of 40.4 $\mu g/m^3$ (South Dakota Department of Water and Natural Resources, 1984b, 1986). The highest concentration was 301.3 $\mu g/m^3$ and only eight samples exceeded 100.0 $\mu g/m^3$. Other counties for which data were available had similar distributions.

3.7 Population

The study areas can be broadly characterized as sparsely settled, rural farmland on very level terrain. The principal land use is agri-

culture; more than 90% of the total land area is designated as farm land. The average population density is less than 10 persons per square mile (U.S. Department of Agriculture, 1982).

The major urbanized area near the proposed operations center site and the study areas in North Dakota is Grand Forks, although two of the North Dakota study areas are nearly as close to Fargo. Thief River Falls is the largest urbanized area near the northern Minnesota study area; Wheaton is the largest town near the west central Minnesota study areas. The urban area closest to the Amherst study area in South Dakota is Aberdeen.

These cities are most likely to realize the largest absolute economic effects from construction and operation of the proposed installations; some of the smaller communities near the potential sites, however, are likely to realize larger relative effects (that is, the greatest proportional changes). Of the 12 counties that in whole or in part comprise the study aras, in only 4 does more than one-half of the population reside in urbanized areas: Cass and Grand Forks counties in North Dakota, Pennington County in Minnesota, and Brown County in South Dakota.

Because economic data are often given by county for convenience, the counties that in whole or in part constitute the study areas are listed in Table 3-3.

Table 3-3

COUNTIES IN THE STUDY AREAS

Study Region	Counties
North Dakota-N	Nelson Walsh Grand Forks Steele
North Dakota-S	Steele Traill Cass
Grand Forks AFB	Grand Forks
Minnesota-N	Pennington Polk
Minnesota-S	Traverse Brown Day Marshall

Population in all study areas is tending to move from the rural to the urbanized areas. Between 1970 and 1980, six of the eight predominantly rural counties lost population in amounts ranging from 5.4% to 17.2% of earlier levels. All urbanized counties gained population in amounts, ranging from 0.1% to 19.8%, between 1970 and 1980. Table 3-4 shows the populations of all counties in the study areas.

3.7.1 North Dakota

The North Dakota-S region is located near the largest city in North Dakota, Fargo, in Cass County. The city's 1980 population was 61,383. The city has roughly 10% of the total state population, and 70% of the county's population.

The operations center would be located in Grand Forks County, North Dakota. In 1980, the county had a population of 66,100; base personnel and their dependents, about 9,400 in all, account for more than 15% of the total. The city of Grand Forks accounted for roughly two-thirds of the county's population, or about 43,765 people.

Table 3-4

COUNTY LAND AREAS AND POPULATION

County	Land Area (mi^2)	Population (1980)
North Dakota		
Cass	1,767	88,247
Grand Forks	1,440	66,100
Nelson	991	5,233
Steele	713	3,106
Trail	861	9,624
Walsh	1,290	15,371
Minnesota		
Pennington	618	15,258
Polk	1,982	34,844
Traverse	537	5,542
South Dakota		
Brown	1,722	36,962
Day	1,022	8,133
Marshall	848	5,404

Source: U.S. Department of Commerce, 1983.

3.7.2 Minnesota

The city of Thief River Falls, the Pennington County seat, had 9,105 residents in 1980; its population declined to about 8,200 in 1985. Much of the decline resulted from depressed economic conditions in agriculture, paralleling a similar county decline, and the dramatic reduction in jobs by the area's largest employer, the manufacturer of Arctic Cat snowmobiles.

Polk County has two urban areas, East Grand Forks and Crookston. Their populations in 1980 were 8,537 and 8,628, respectively. County population has been relatively stable or grown slightly over the decade.

Wheaton, in Traverse County, now has about 1,960 residents, compared with 1,976 in 1980. The county has also experienced a continuous decline over the past four decades.

3.7.3 South Dakota

The largest urban area near the South Dakota study area is the city of Aberdeen, in Brown County. In 1980, the city had a recorded population of 25,956, 70% of the county total and 51% of the population of the study area. Day and Marshall counties have no urbanized areas with more than 2,500 people.

3.8 Economy

3.8.1 Employment

3.8.1.1 North Dakota-N (Dahlen and Goose River)

The region west of Grand Forks AFB, has a combined labor force of about 47,000. Unemployment is approximately 4.5-5.5% of the labor force. (University of North Dakota, 1983; U.S. Department of Commerce, 1983; Boyd, 1986).

Grand Forks County dominates employment in the region, accounting for 75% of the total these counties. The Air Base is a dominant employer in the area. Within Grand Forks County, trade, finance, and services provide about 40% of the region's jobs, all levels of government account for about 35%, and agricultural employment is about 10-15% of total employment.

3.8.1.2 North Dakota-S (Galesburg and Blanchard)

This region has a total labor force of approximately 61,000. Cass County has the largest labor force in the region. It totals approximately 55,000, and accounts for about 90% of the regional total.

For the three-county region, about 55% of total employment is in trades, finance, and services, 18% is in government, and 7-8% is in agriculture. For Steele and Traill Counties alone, the distribution of employment is 36% in trades, finance, and services, 16% in government, and 35-40% in agriculture.

3.8.1.3 <u>Minnesota-N (Thief River Falls)</u>

This region has a labor force of approximately 25,000. Unemployment is 8-10%. Finance and services account for slightly more than 27% of total employment, farming for about 25%, wholesale and retail trade accounts for about 17%, federal, state, and local government for about 15.5%, manufacturing for about 8%, and the remaining occupations for 7.5% (U.S. Department of Commerce, 1983; Huggett, 1986).

3.8.1.4 <u>Minnesota-S (Wheaton N, Wheaton SE, and Wheaton SW)</u>

Employment in Traverse County is approximately 2,200, and the unemployment rate is about 8-9%. Farming is the dominant source of employment in the area, accounting for nearly 38% of all jobs. Wholesale and retail trades provide 19% of the jobs, federal, state, and local government contribute 18.5%, finance and services provide nearly 16%, and all other trades account for the remainder (U.S. Department of Commerce, 1983; Minnesota Division of Economic Services, 1986).

3.8.1.5 <u>South Dakota (Amherst)</u>

The city of Aberdeen, with a population of about 26,000, is in Brown County; Brown County is the regional employment and population center for this part of South Dakota.

The total labor force in the three counties is approximately 25,000, and the unemployment rate is currently about 6.1%. The labor force in Marshall and Day Counties is about 20% of the total for the three counties; the region is economically dominated by urbanized Brown County. For employment covered by unemployment insurance, which accounts for roughly 70% of the labor force, the major job categories are wholesale and retail trades (30%), finance and services (27%), government (19%), manufacturing (16%); and other categories (8%). Farming accounts for approximately 15-20% of the total labor market (U.S. Department of Commerce, 1983).

3.8.1.6 <u>Grand Forks AFB</u>

The base is located approximately 15 miles west of the city of Crand Forks, North Dakota, in Grand Forks County. It is a major center of economic activity in the region. More than 5,000 active military personnel and more than 1,500 civilians work on the base; they account for more than 20% of the County's total employment.

The labor force in Grand Forks County totals approximately 35,000; unemployment currently ranges between 3.5 and 4.5%, or about 1,500 people depending on the season. The major source of employment in the county is federal and state government, including the Air Force, which altogether account for about 40% of total employment. Trade, finance, and services also account for about 40% of total employment. Although the region is in the heart of agricultural territory, direct agricultural employment is only 5-6% of the county's total employment.

3.8.2 Income

Aggregate Personal Income for the United States grew by 24.6% between 1981 and 1984. As shown in Table 3-5, income grew at similar or greater rates in only one-third of the project region counties. These data indicate the continued depression in farming. As indicated in the table, average per capita personal incomes in 1984 for residents of the North Dakota counties were approximately equal to the national average, ranging from 92% of the U.S. average in Nelson County to 127% of the U.S. average in Steele County. The Minnesota counties had lower per capita income levels, 85% to 92% of the U.S. average. In South Dakota, the residents of Day and Marshall counties had average per capita personal income of 82% of the U.S. average; residents of Brown County averaged 94% of the U.S. average. In general, per capita income in the rural areas, with some exceptions in North Dakota, reflect the depressed economic conditions in the region.

3.8.3 Fiscal Conditions

Tax levies differ substantially for each constituent township within the counties in the study areas. The levies include school district assessments, sinking funds, fire protection charges, building funds, and the like. Rates and assessments within each study area are highly diverse.

3.8.4 Farm Income and Values

A variety of crops and livestock are produced in the study areas (see also Section 3.4.3). Major crops include corn, wheat, oats, barley, flaxseed, soybeans, sugar beets, sunflowers, and hay. Livestock includes sheep, hogs, cattle, and poultry. Available statistics indicate that average 1982 gross farm income in the study regions ranged between $75,000 and $100,000 (U.S. Department of Agriculture, 1982). Net income on farms--i.e., the difference between gross income and the costs of production (e.g., fertilizers, equipment, labor, etc.)--is estimated to be approximately 10-20% of gross income, ranging from $7,500 to $20,000 per year per farm.

The highest gross incomes per farm in 1982 were realized in the two North Dakota regions, these averaged $95,806 and $101,041 for the North and South regions respectively. Traverse County, Minnesota was slightly behind the North Dakota-N region at $94,617, the Minnesota-N region had the lowest income among the five study regions, slightly behind the

Table 3-5

TOTAL PERSONAL AND PER CAPITA INCOME, 1984

County	Total Personal Income		Per Capita Income	
	1984 $	% Change, 1981-1984	1984 $	% of U.S. Average
North Dakota	$8,437	18.4%	$12,290	96.2%
Cass	1,320	27.3	13,943	109.2
Grand Forks	763	23.1	11,060	86.6
Nelson	70	22.8	13,878	108.7
Steele	45	12.5	15,065	118.0
Traill	130	16.1	13,865	108.6
Walsh	184	17.2	11,752	92.0
Minnesota	$54,983	24.8%	$13,212	103.4%
Pennington	153	18.6	10,866	85.1
Polk	388	19.4	11,490	90.0
Traverse	63	28.6	11,680	91.5
South Dakota	$ 7,696	23.0%	$10,904	85.4%
Brown	440	19.2	11,966	93.7
Day	85	30.8	10,661	83.5
Marshall	55	27.9	10,439	81.7

Source: U.S. Department of Commerce, 1986.

South Dakota counties, at $74,804. The South Dakota region averaged $74,930. Because of local conditions, types of crops planted, and a variety of other circumstances, dollar yields per acre vary significantly in the project region. Some farmers are doing well, others are surviving, and some are failing. Statistics for average farms in the study regions are presented in Table 3-6. Although these data are somewhat out of date, more recent data on property values indicate a significant decline. This decline reflects soft commodity prices and a continued depression in farming.

3.8.4.1 North Dakota-N (Dahlen and Goose River)

According to 1982 data, the 3,004 farms with about 2.7 million acres in the North Dakota-N counties averaged 893 acres, the largest among the five study regions. Total gross income for all farms in the region was $287.8 million, an average of just over $107 per acre or $95,806 per farm.

Farm land values reached their peak in 1981 or 1982, when values for the entire area averaged about $663 per acre based on land sales (Johnson, 1986).* Since 1981, values have fallen by approximately 30% to about $450 per acre in 1985. Between 1984 and 1985 alone, values fell by about 15-20%. Recent increases in crop futures prices, which may be of short duration, may improve values slightly. However, the current year's production will have the most important impact on farm financial conditions and property values. Indications are that commodity prices will continue to weaken.

3.8.4.2 North Dakota-S (Galesburg and Blanchard

The three counties of this study region have 2,401 farms totaling more than 2 million acres, for an average of 846 acres per farm. Average gross income in 1982 was about $120 per acre, or $101,041 per farm. For the two counties most likely to be affected by the CRS, Steele and Traill, the 1,125 farms average 864 acres and account for $114 million total income or $101,333 per farm and $117 per acre.

In 1981, farm values in the region were about $935 per acre.† After falling by about 35%, average values in 1985 were about $600 per acre; higher values were realized for property closer to the Red River Valley.

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*Estimates for the North Dakota-N region are based on simple averages of the Northeast Central, North Red River Valley, and Southeast Central regions.

†Estimates for the North Dakota-S region are based on average values in the South Red River Valley and Southeast Central regions, assigning a double weight to the Red River area.

Table 3-6

AVERAGE FARM CHARACTERISTICS, 1982

	Total Farms (Number)	Total Acres (Number)	Total Income (10^6 $)	Average Income/Farm ($)	Average Farm Size (Acres)
North Dakota					
North	3,004	2,683.1	$287.8	$95,806	893
South	2,401	2,031.1	242.6	101,041	846
Minnesota					
North	2,429	1,408.0	181.7	74,804	580
South	483	330.3	45.7	94,617	684
South Dakota	2,517	2,095.9	188.6	74,930	833

Source: U.S. Department of Agriculture, 1982.

3.8.4.3 Minnesota-N (Thief River Falls)

Of the two counties making up this study region, Pennington and Polk, Polk County has significantly more land dedicated to farming and dramatically higher productivity than Pennington. For the region as a whole, 2,429 farms average 580 acres in size. Aggregate annual income in 1982 was approximately $75,000 per farm and $129 per acre.

Polk County farms accounted for 73% of the total number and 78% of the acreage for the region. Aggregate annual incomes in the richer valley land averaged nearly $89,000 per farm and $144 per acre, compared with Pennington County's $37,000 per farm and $78 per acre. According to a recent press release from the governor's office, land values in Pennington County range between $300 and $500 per acre, whereas those in Polk County average roughly $1000 per acre.

In Pennington County, the number of farms declined from 817 in 1969 to 655 in 1982, a drop of 20%. Between 1970 and 1980, farm population fell by nearly 40%, from nearly 3,000 to just over 1,800. In Polk County during the same two periods, the number of farms fell from 2,361 to 1,774--by 25%--and farm population declined from 8,776 to 5,024--by 43%. For the two counties combined over these same periods, the number of farms fell by 24% and farm population by 42%.

3.8.4.4 Minnesota-S (Wheaton, Wheaton SE, and Wheaton SW)

Traverse County contained 483 farms in 1982 on 330,450 acres, for an average size of 684 acres. This area had aggregate farm sales of nearly $46 million and an average annual gross income of about $95,000 per farm and $138 per acre. The number of farms declined by 186 between 1969 and 1982, a drop of 28%; farm population declined by more than 25% between 1970 and 1980, to about 1,839.

3.8.4.5 South Dakota (Amherst)

The three-county region near the study area had 2,517 farms in 1982 on 2.1 million acres, an average of 833 acres per farm. In Day and Marshall counties, the ones most likely to be affected by the CRS, there were 1,326 farms on just over 1 million acres, for an average 791 acres per farm. Income for the combined region totalled about $189 million--$90 per acre and about $75,000 per farm. Income for the two counties totalled about $85 million--$64,000 per farm and $81 per acre.

Land values peaked in 1982 for most South Dakota farm land, averaging between $269 and $435 per acre. By 1984 values had decreased by 10% or more, to average between $245 and $383 an acre; this trend was similar to the experience in North Dakota. Presumably, as in other areas in the region, values have continued to decline.

3.9 Housing

An abundance of available housing characterizes most of the project region. Between 8% and 10% of the year-round housing stock is currently vacant, and much of it is available for rent. Although detailed data are not available, temporary housing sites, such as equipped mobile home sites, are considered to be abundant and new temporary sites are easily accommodated.

Estimates of 1980 year-round housing stock and vacancies are shown in Table 3-7. These estimates are likely to understate current vacancies because several of the counties have experienced measurable declines in population and households over the past several years.

Total vacant units in 1980 for the North Dakota-N region were 3,688, 10.8% of total year-round units. The North Dakota-S region had 3,155 vacant units, 7.8% of the year-round housing total. Both Minnesota regions had vacancy rates in excess of 10%; or more than 2,000 units in the North and 239 in the South. Average vacancy in the South Dakota counties totalled 8.9%, or 1,780 available housing units.

In addition to permanent and semipermanent housing, the cities of Grand Forks, Thief River Falls, Fargo, and Aberdeen have a large number of hotel and motel units.

Table 3-7

YEAR-ROUND HOUSING STOCK AND OCCUPIED UNITS, 1980

County	Housing Units	Occupied Units	Percent Vacant
North Dakota			
Cass	35,129	32,613	7.2%
Grand Forks	24,435	22,108	9.5
Nelson	2,410	1,983	17.7
Steele	1,365	1,142	16.3
Traill	3,843	3,427	10.8
Walsh	5,955	5,244	11.9
Minnesota			
Pennington	5,945	5,437	8.5
Polk	13,659	12,154	11.0
Traverse	2,277	2,038	10.5
South Dakota			
Brown	14,504	13,357	7.9
Day	3,346	2,980	10.9
Marshall	2,234	1,967	12.0

Source: U.S. Department of Commerce, 1983.

3.10 Community Services and Facilities

3.10.1 Education

Enrollment of persons 3 years and older in the study area counties ranged from 668 to 16,068 in 1980. Total enrollment in the North Dakota-N region was 16,851; enrollment in the North Dakota-S region was 18,553. Enrollment in the Minnesota-N counties totalled 10,712. Traverse County, encompassing the Minnesota-S region, had a total enrollment of 1,219. Total enrollment in the three South Dakota counties was 10,436 (U.S. Department of Commerce, 1983). Many of these regions have surplus school capacity due to a loss of school age population over the last decade or more.

In addition, the North Dakota regions have large college enrollments. Cass County has a college enrollment of 9,370, largely on the North Dakota State University campus in Fargo: just over 2,300 are from the county. Grand Forks County, with the University of North Dakota, has a college enrollment of 8,851, nearly 2,800 from the county.

3.10.2 Health Care

The four major indicators of the regional health care system are the number of physicians, hospital beds, nurses, and dentists per 100,000 population. Compared with the national average, only the North Dakota-S region exceeds the U.S. rates for all four indicators. The North Dakota-N region also compares favorably to the national averages, with only slightly fewer physicians per capita than the nation as a whole. The Minnesota regions, except for number of hospital beds, are significantly lower than the national and state averages. However, larger regional medical facilities are available close to Grand Forks, Fargo, and Thief River Falls. The South Dakota region exceeds the national averages in hospital beds and nurses, but is at 60% of the national average for physicians and 85% for dentists (U.S. Department of Commerce, 1983).

3.10.3 Roadways

Transmit and receive sites would be located in areas remote from large population centers where the most important infrastructure features are county roads and drainage systems. Drainage systems, which are usually in the form of drainage ditches and canals, are peculiar to an area and its relative elevation with respect to adjoining property.

County roads generally criss-cross the study areas at section intervals. Some of these roads are rarely used; some have even been farmed over. Others, however are actively used for access to homes, fields, and other areas.

As a general rule, each 1 mile square section within each study area is bounded by either a county or a township road. At some locations state and U.S. highways are exceptions to this rule. Where no clearly defined road is found, a county or township right of way usually exists. Roadways within the study areas are predominantly gravel and are oriented north to south and east to west. Access within the 1 mile square sections is on private drives, when they exist. The condition of county and state roads is reported as good. No roadway grades that might limit vehicle access are apparent.

For the most part, existing roadways within the study areas can be categorized as one of the following:

Primary Road, Heavy Duty--predominantly U.S. or state multilane roadways. Surface is all-weather and paved.

Secondary Highway, Medium Duty--predominantly state-constructed and -maintained roads. They generally have an all-weather, hard bituminous surface with a 28- to 32-ft traveled width.

Light Duty Road- predominantly county- and township-maintained, all-weather roadways with either a bituminous or an improved gravel surface. The traveled width of these roads is approximately 24 ft for paved surfaces and 26 to 28 ft for improved gravel surfaces.

Unimproved Road--predominantly township-maintained or privately maintained fair or dry weather roadways. Surfaces are either gravel or existing natural surface materials. Roadway widths are not uniformly defined.

Traffic volume is light on most roads within the study areas. Secondary highway traffic typically consists of automobiles, local trucks, farm equipment, and a small volume of long-haul trucks. Because the population is sparse, the volume of traffic on the light duty and unimproved roads consists primarily of farm equipment and is very light. Traffic data for specific study areas are not available.

Most improved roadways and some unimproved roads within the study areas contain drainage culverts, particularly at roadway intersections. There are also several small bridges and concrete box or arch culverts within each study area, generally at river or stream crossings. Most roadway and rail crossings are at grade.

3.10.3.1 Study Areas

In North Dakota and South Dakota, both state and county roads are generally capable of handling 20-ton vehicle loading (AASHTO, 1977). The specific capacity is posted for some bridges and culverts, but not for others. Culverts and bridges on state and county roads are generally capable of handling 20-ton design loads (AASHTO, 1977). Culverts on township roads are generally capable of handling 15-ton design loads (AASHTO, 1977); however, actual capacity varies depending on roadway culvert conditions (Enrud, 1986; Hier, 1986; McKinnen, 1986; Onstad, 1986; Schaub, 1986)).

The state of Minnesota imposes load restrictions on its roadways. Unless posted otherwise, a restriction of 9 tons/axle with a total vehicle weight of 80,000 pounds must be adhered to during the summer months, and 7 tons/axle is the maximum during the spring. Township roads are limited to 5 tons/axle during the spring (Schaub, 1986). In general, access along unimproved surfaces is difficult during wet periods.

Drainage within the study areas is generally poor because of the low soil permeability. Roadways are generally built above the surrounding terrain. Fill used for this purpose is obtained by excavating drainage ditches adjacent to the roads and importing borrow material for either the base course or a gravel surface. Roadway side slopes of 4:1 for state or county roads and 3:1 or steeper for township roads are the norm (Onstad, 1986).

3.10.3.2 Grand Forks AFB

Grand Forks AFB is in Grand Forks County, North Dakota, approximately 15 miles west of downtown Grand Forks. Major roadway access to the base is via Interstate Route 29, which runs north-south, and U.S Route 2, which runs east-west. Access within the region is by a combination of paved and graveled county routes. Access to the main gate of Grand Forks AFB is from County Road 3, which intersects U.S. Route 2 to the south. Approximately 1 mile south and parallel to U.S. Route 2 lies a railroad line owned by Burlington Northern.

The proposed operations center site at Grand Forks AFB is the area bounded to the south by 1st Avenue, to the west by G Street, and to the north by Base Facilities 306 and 304, as shown in Figure 3-2. Vehicle access would be through the Main Gate; traffic would then move along Steen Boulevard, turn left on G Street, and then turn left on 1st Avenue. The preferred construction access is through the South Gate (west of County Road 3 along U.S. Route 2) to Eielson Street, right on 1st Avenue, and past G Street to the proposed site.

3.10.4 Solid Waste

3.10.4.1 North Dakota N

Solid waste landfills serving the Dahlen and Goose River study areas are located in Park River, Larimore, and Northwood, North Dakota. An additional landfill serves the Niagra region located south of Michigan, North Dakota. Larimore's landfill is classified as a geologically unsuitable landfill that is closed or scheduled for closure (North Dakota Department of Health, 1986). Rural pick up of solid waste is available in some portions of the study areas. Most landfills require segregation of materials.

3.10.4.2 North Dakota-S

Solid waste landfills serving the Galesburg and Blanchard study areas are located in Hillsboro, Mayville, and Hunter, North Dakota. In addition, a landfill located in Enderlin, North Dakota, serves the Clifford and Galesburg areas. The landfills in both Hillsboro and Hunter are geologically unsuitable landfills that are closed or scheduled for closure (North Dakota Department of Health, 1986). Most landfills require segregation of waste materials.

3.10.4.3 Minnesota-N

A county landfill serving the Thief River Falls study area is located south of the study area in Crookston, Minnesota. Rural pick up of solid waste is available throughout much of Polk County (North Dakota Department of Health, 1986).

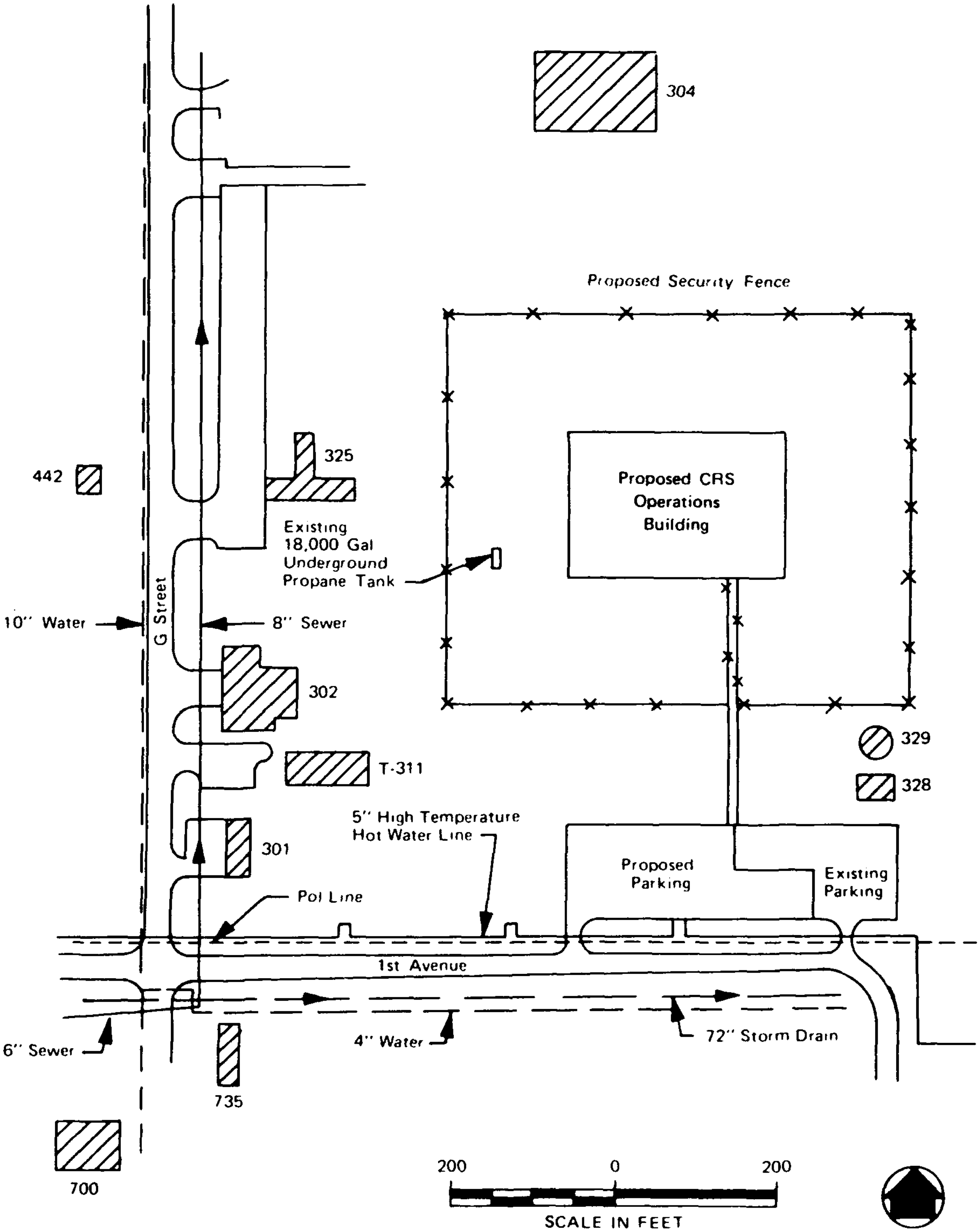


FIGURE 3-2 PROPOSED CRS OPERATIONS BUILDING LOCATION, GRAND FORKS AIR FORCE BASE

3.10.4.4 Minnesota-S

No solid waste landfills exist in the immediate vicinity of the three Wheaton study areas. The nearest landfill is in Beardsley, Minnesota, southwest of the study areas.

3.10.4.5 South Dakota

No solid waste disposal sites have been identified within the Amherst study area. Landfills have been identified, however, in Groton to the southwest, Britton to the east, and Crandall to the south. It is likely that rural pick up exists, at a minimum, within the several communities in and adjacent to the study area.

3.10.4.6 Grand Forks AFB

Disposal of base solid waste is accomplished by a private contractor, who transports the waste material to the Grand Forks city landfill approximately 10 miles east of the base (Koop, 1986).

3.11 Aesthetics

The nine study areas are located in a region where most of the native grasslands and prairie wetlands that originally provided the mosaic of color and texture have been converted to agricultural use. The visual resources in the region are generally characterized as homogeneous and reflect the flat to gently rolling topography of agricultural croplands. The angular and repetitive pattern and color of the cultivated fields, typically bordered by single-row tree breaks, form the dominant visual elements in the landscape scene. The flat, open landscapes offer expansive views from primary viewing points such as roads, recreational areas, and residential developments.

Some study area landscapes include small blocks of wooded areas, natural waterways (lakes, ponds, creeks, rivers), wetlands, and floodplain areas. These natural features, which provide important habitats for the wildlife of the region, contribute to the diversity of color, line, and texture in the landscape.

Human modifications in the study areas include transmission line towers and utility lines, roads, isolated groupings of agricultural buildings (silos, barns), and farm equipment. Because of the flat, open setting and the lack of intervening vegetation, these man-made features dominate the landscape scene and are silhouetted along the horizon.

The lack of natural topographic features of interest, the lack of visual diversity, and the dominance of human modifications in the study area landscapes result in a moderate to low rating for scenic quality for the study areas. Viewer sensitivity ranges from low to moderate for

most study areas where small farm communities and roads are within viewing distance of possible CRS sites. None of the nine study areas is within sensitive viewing distance of scenic overlooks or major recreation resources. Appendix E summarizes scenic quality and viewer sensitivity characteristics for each of the nine study areas.

3.12 Cultural Resources

3.12.1 Overview

For treatment of cultural resources, the study region is defined as the central portion of the Northeastern Plains culture area. The region contains the southern portion of former glacial Lake Agassiz and the northern portion of former glacial Lake Dakota.

The last major continental glaciers receded from most of the study region by 11,500 years ago (or years before present, BP). The South Dakota study area had been covered by the James Lobe of the Laurentide continental ice sheet, and the other study areas had been covered by the Red River Lobe (Brophy and Bluemle, 1983; Flint, 1955). At other places in the North American Plains, the earliest solid evidence for the presence of man dates to this approximately 21,500 years BP (Frison, 1978; Haynes, 1966). However, the study region failed to attract settlement by the earliest Native Americans because of its inhospitable and recently deglaciated landscape, and its low density of large game. It was not until 10,500 BP or so, after the natural environment changed during terminal Pleistocene-early Holocene times, that the study region was settled.

A Northeastern Plains cultural chronology is appropriate for the entire study region because all study areas are in the Plains, west of the prairie-woodland ecotone. This ecotone has been to the east of the study region since the early Holocene. The cultural history of the prairie-woodland transition zone is an especially dynamic one. This zone was the interface between people with lifeways adapted to woodland resources and those adapted to plains resources. The transition zone is just a short distance to the east of the Minnesota study areas.

The nine OTH-B study areas, with their combined total area of nearly 800 square miles, hold very few cultural properties that have been formally recorded with the State Historical Society of North Dakota (SHSND), the Minnesota Historical Society, and the Office of the South Dakota State Archaeologist. These are the official repositories of records concerning prehistoric and historic cultural sites in the three states. Table 3-8 provides summary descriptive information concerning the sites, find spots, and site leads that are recorded within the bounds of the nine study areas, and the map in Figure 3-3 shows their locations. No sites, either recorded or unrecorded, are listed in the National Register of Historic Places.

Table 3-8

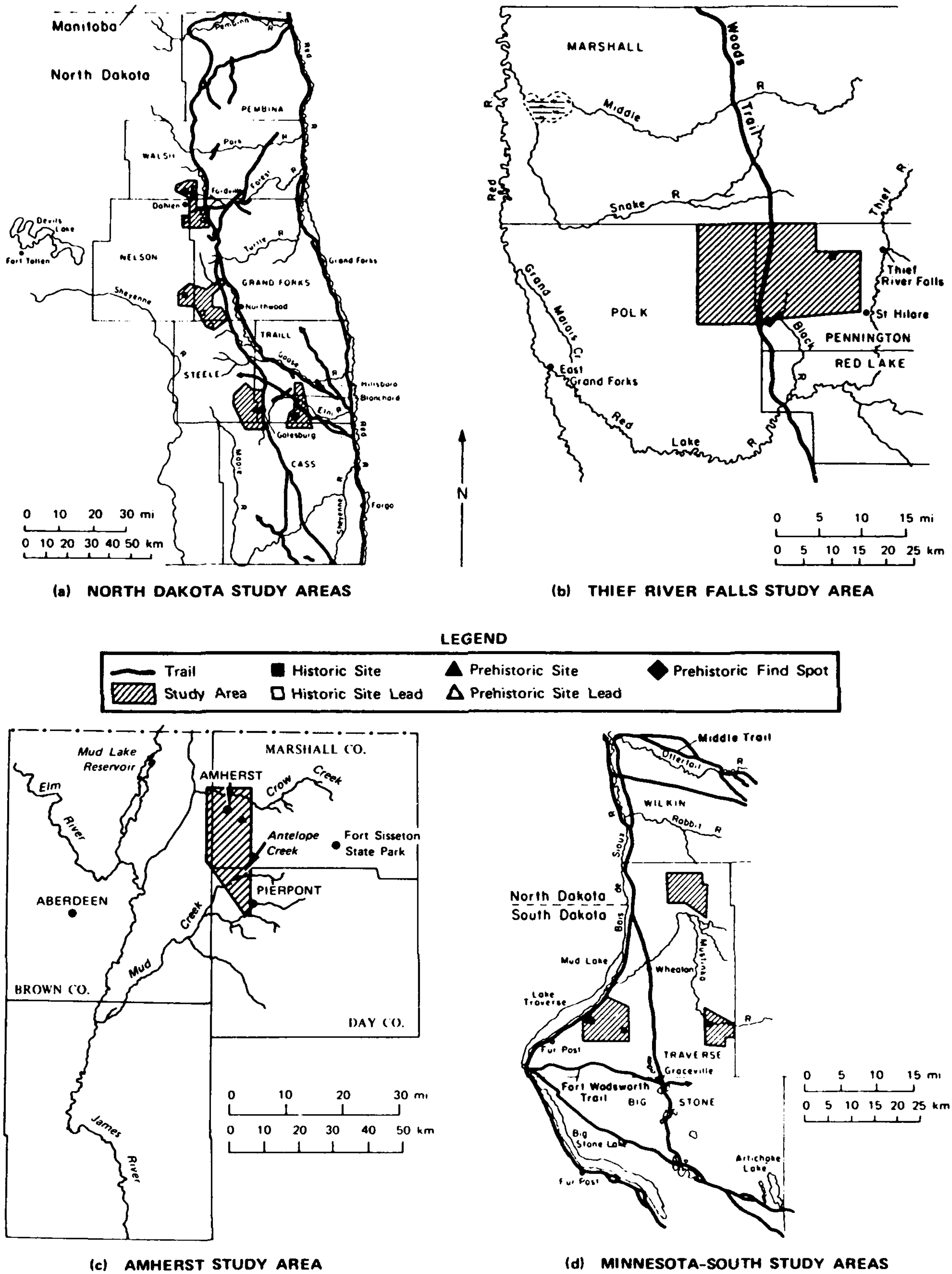
RECORDED SITES, FIND SPOTS, AND SITE LEADS

Sites/Leads	Legal Location	Site Type	Affiliation
Dahlen			
Historic Site Leads			
Pioneer grave	Sec 34, T. 154 N. R. 56 W.	Possible grave	Historic
Baconville P.O.	Sec 35, T. 154 N. R. 57 W.	Post office	Historic
Belleville P.O.	Sec 14, T. 154 N. R. 56 W.	Post office	Historic
DeWar Siding	Sec 17, T. 155 N. R. 56 W.	Structure	Historic
Tomey P.O.	Sec 29/30, T. 155 N. R. 56 W.	Post office	Historic
Proha P.O.	Sec 22, T. 155 N. R. 57 W.	Post office	Historic
Goose River			
Historic Site Leads			
Tara Settlement	Sec 5, T. 148 N. R. 56 W.	Post office	Historic
Rugby P.O.	Sec 32, T. 150 N. R. 57 W.	Post office	Historic
Running Stage	Sec 20, T. 149 N. R. 56 W.	Stage stop	Historic
Galesburg			
Prehistoric Site Lead			
Looted mound	Sec 13, T. 144 N. R. 54 W.	mound[a]	Unknown
Blanchard			
Historic Site Leads			
Weible P.O.	Sec 24, T. 144 N. R. 52 W.	Post office	Historic
Greenfield	Sec 24, T. 144 N. R. 52 W.	Railroad station	Historic
Thief River Falls			
Prehistoric Site			
21PE1	Sec 9, T. 152 N. R. 45 W.	CM scatter[b]	Woodland
Prehistoric Find Spot			
21PE9002	Sec 3, T. 152 N. R. 45 W.	Unknown	Old Copper
Historic Site			
First house in Pennington Co.	Sec 32, T. 154 N. R. 44W.	Farmstead	Late 1800s

Table 3-8 (Concluded)

Sites/Leads	Legal Location	Site Type	Affiliation
Wheaton N			
None			
Wheaton SE			
Historic Site			
Dollymount	Sec 28, T. 126 N. R. 45 W.	Town hall	About 1910
Wheaton SW			
Prehistoric Sites			
21TR1	Sec 23, T. 126 N. R. 48 W.	Mound	Cambria, Kathio
21TR21	Sec 23, T. 126 N. R. 48 W.	Mound	Unknown
21TR22	Sec 23, T. 126 N. R. 48 W.	Mound	Unknown
21TR23	Sec 23, T. 126 N. R. 48 W.	Mound	Unknown
Historic Sites			
Bartz Farm	Sec 34, T. 126 N. R. 47 W.	Farmstead	1895
Windsor	Sec 23, T. 126 N. R. 48 W.	Town hall, school	About 1900
South Dakota			
Prehistoric Site			
39ML40	Sec 19, T. 126 N. R. 58 W.	CM scatter	Unknown

[a]Mound of earth covering an aboriginal grave.
[b]Cultural material scatter (e.g., fire-cracked rocks, pottery sherds, stone tools, etc.).



SOURCE: Gilman et al. (1979)

FIGURE 3-3 RECORDED SITES, FIND SPOTS, AND SITE LEADS

Intensive ground surveys that have been conducted in the study region indicate that each of the study areas probably has an average of at least one prehistoric site per square mile. However, only six prehistoric sites have been recorded within the the nine study areas. The more than 100-fold difference between anticipated site densities and recorded site densities is attributed to the lack of systematic site inventory work in the study areas. Results of site file searches and literature reviews do not enable accurate projections regarding site diversity and site density in the study areas. However, investigations conducted in the greater study region have identified several landforms with higher-than-average site density; these results indicate that many unrecorded sites probably exist in the study areas.

All states use SITS numbers. A SITS number (e.g., 32GF1) consists of three parts. The first number is a state code; 32 indicates North Dakota in this case. The pair of letters indicates a county within North Dakota (e.g., GF = Grand Forks). The next number identifies the site within the county. Locations with no structural remains and a paucity of artifacts are recorded as "find spots." Information concerning find spots and other possible sites is registered in a "site leads" file. In Minnesota, prehistoric sites are assigned SITS numbers, but historic sites are recorded only by name. Find spots are registered with a special SITS number. In South Dakota, as in North Dakota, both prehistoric and historic sites are registered with SITS numbers.

3.12.2 Prehistory and History

The Prehistoric Period is provisionally dated from 10,000 BP to 1859 A.D. in the study region. This period covers the time from the initial arrival of people in the region until settlement by Euro-Americans became firmly established. The Historic Period covers 1860 to 1930.

3.12.2.1 Prehistoric Period

The lifeways of the earliest Native Americans (Paleo-Indian Period, 10,000-7,000 BP) were based on hunting and gathering adaptations to the early Holocene climates, plants, and animals. This period gave way to the Plains Archaic Periods (7,000-2,300 BP) whose lifeways were similar but were adapted to essentially modern resources. Early, Middle, and Late Plains Archaic periods are identified for the study region and are differentiated on the basis of changes in projectile point styles. Plains Woodland lifeways (300 B.C.-1750 A.D.) are thought to have been similar in many ways to those of the preceding Plains Archaic periods. However, the practice of mound burial mortuary ceremonialism, the production and use of ceramic vessels, and the possible intensification in the use of indigenous seedy plants and grasses for food appear to have been Plains Woodland developments. Gathering and processing wild rice (Jenks 1900) was a Woodland development.

The Protohistoric period (1750-1859 A.D.) was a time of Euro-American cultural impact on Native cultures, but it occurred before the historical records began to be kept in the study region. Although traders had contact with Native Americans as early as the mid-1600s, it was not until 1750 that rapid cultural change resulting from European influences began. The Protohistoric period was marked by exploration of the region by government expeditions and the establishment of fur trading posts, commercial interest groups, and trade fairs where European goods were traded for horses, buffalo, and other items (Holzkamm, 1983). The growing impetus of the fur trade in the region during the early 1800s necessitated the movement of materials and information between the British Hudson's Bay Company settlements in Manitoba and the existing American settlements in southern Minnesota. Trails linking Selkirk Colony in southern Manitoba with St. Paul and Mendota, Minnesota, were established between 1820 and 1870. The networks of trails are commonly referred to as the Red River Trails (Gilman et al., 1979). All eight of the North Dakota and Minnesota study areas were on or near parts of these trails, and cultural resources associated with the early historic settlement of the region can be expected to occur adjacent to these trails.

3.12.2.2 Historic Period

Several events of the late 1850s and early 1860s profoundly affected resettlement of the region. Minnesota became a state in 1858. In the following year, the Sioux Indians ceded a large tract of land to the U.S. government. The tract became Dakota Territory in 1861. Conflicts between the Dakota and non-Indian settlers led to the Sioux Uprising of 1862 in Minnesota. The U.S. military took direct control over lands within Dakota Territory and built military installations within the region.

In the next few years, non-Indian settlement increased slowly following U.S. government land surveys of the early 1870s and the opening of Dakota Territory for homesteading in 1871. In 1870, only 13 Euro-Americans resided in Traverse County, Minnesota (Beissel et al., 1984). During parts of the next two decades, Euro-American settlement boomed (Briggs, 1930). The expansion of rail service into the region, combined with demand for food crops and high crop yields in the region, drew a great influx of people. North Dakota and South Dakota were admitted to the Union in 1889. A second boom occurred in North Dakota between 1900 and 1917. World War I brought immigration to an end, and the population of the study region was stable from 1920 to 1930.

3.12.3 Study Areas

3.12.3.1 Dahlen

Cultural resource investigations within the boundaries of this study area are limited to portions of two survey projects conducted in 1977 and 1978. An archeological and historical reconnaissance survey of the Great Lakes Gas Transmission Company pipeline route included a

portion of Section 7, T. 154 N., R. 56 W. as well as locations adjacent and near to the study area (Woolworth Research Associates, 1978). A cultural resource inventory for the proposed channelization work on the Turtle River included portions of Sec 6, 7, 18, T. 153 N., R. 56 W., and Sections 30, 31, T. 154 N., R. 56 W. as well as numerous other locations in the region (Loendorf, 1977). No cultural resource properties were located within the present study area by either of these previous surveys. One site lead on record at the SHSND is the possible grave of a black pioneer. Tweton (1978) indicated the locations of several possible historic sites/structures that could be of significance. They are the Baconville Post Office, the Belleville Post Office, DeWar Siding, the Tomey (Toma) Post Office, and the Proha Post Office.

Both the Middle and the South branch of the Forest River traverse the study area, and locations along these streams are extremely likely to have been used as intensively by prehistoric groups as the area immediately to the east. A portion of what is probably the Ridge Trail was recorded 4 miles east of the study area (Larson et al., 1986). Travel routes and archeological evidence of the Metis and earliest Euro-Americans in the area have particularly important research potential.

3.12.3.2 Goose River

Within the study area, no cultural resource inventories have been conducted, and no cultural resource properties have been identified. Possible sites of historical significance indicated by Tweton (1978) are the Tara Settlement Post Office, the Rugby Post Office, and the Running Stage Stop. A survey of selected locations in the Goose River basin included areas south and west of the study area (Nicolai et al., 1978). One prehistoric burial mound site, 32GF10, is recorded within a mile of the east-central study area limits near the Goose River (Cole, 1968b). The Anderson-McDonald Mound (32GF325) is situated 5 miles northeast of the study area. A site lead on record at the SHSND indicates that a mound is 1 mile north of the study area. Other mound sites are purportedly within a few miles southeast of the study area near Beaver Creek. Cultural resource inventories for the Garrison Diversion Project conducted near Stump Lake and the Sheyenne River 15 miles west of the study area in western Nelson county located numerous prehistoric sites, primarily mounds.

The prospects for locating prehistoric sites within the study area are good, particularly along the Goose River and prairie pothole lakes and sloughs. Remnants of the Ridge Trail route probably are still visible; these would be an important historical and cultural resource.

3.12.3.3 Galesburg

No systematic cultural resource survey has been conducted within the study area, and no sites are recorded. One site lead covers a looted mound and an old railroad grade is indicated along the northeastern perimeter of the study area. The historic Ridge Trail also parallels the eastern study area perimeter, but railroad construction and a modern road may have obliterated any traces of it.

The South Branch of the Goose River flows through the northwestern part of the study area. Prehistoric human burial mound sites and cultural material scatters have been found on the Goose River farther northeast, and they probably are also present on this tributary. The potential for prehistoric sites within the study area is high.

3.12.3.4 Blanchard

Systematic cultural resource inventories have not been conducted within the study area, and no historic or prehistoric sites are recorded there. The Weible Post Office, and the Greenfield Railroad station, may be sites of historical significance (Tweton, 1978). The Preston Great Northern Station, immediately adjacent to the study area, may also be an important site (Tweton, 1978). A historic trail from Fort Abercrombie to Fort Totten traverses the study area and may still be visible in untilled areas because it is more recent than the Ridge Trail to the west (Gilman et al., 1979).

The Elm River, which bisects the study area, would most likely have attracted prehistoric occupation, and evidence is likely to exist for prehistoric use of the river and its tributaries. The remains of early Euro-American exploitation of the area may also be present, and remnants of the trail should be evident in areas that have not been cultivated.

3.12.3.5 Thief River Falls

Within this study area, only one prehistoric site, one prehistoric find spot, and one historic site have been recorded. All are in Pennington County. No sites were recorded in the Thief River Falls study area in Polk County. No sites in the study area are listed in the National Register of Historic Places. No systematic cultural resource survey, testing, or excavation has been conducted in this study area.

Within the study area, Carpenters Corner is the only town. Thief River Falls is 3 miles east of the area. The Woods Trail crosses the study area in a north-south direction. This trail was established in 1844 in Ojibway territory as an alternative route to Pembina to avoid hostile Dakota Indians (Gilman et al., 1979).

One prehistoric site and one prehistoric find spot have been recorded in the study area. The recorded site (21PE1) is an artifact scatter (grit-tempered pottery, chert knife, grooved maul, and socketed copper spear point). Materials collected indicate a Woodland component.

This site is situated on the west bank of Black River. The find spot (21PE9002) is situated 1 mile west of Black River. A copper spear point was recovered, indicating a possible Old Copper Archaic component.

One historic site has been recorded within the study area. The site is referred to as the First House in Pennington County. This farmstead was constructed late in the 19th century.

Evidence from surrounding areas indicate that mounds are frequently located on the surface of the Campbell beach and on the Sand Hill River delta region of former glacial Lake Agassiz (Johnson, 1973). In addition, several copper artifacts have been found in Polk and Pennington counties on the Campbell beach and inside Ojata beach (Johnson, 1964a). Expected cultural traditions likely to be present in the study area include Paleo-Indian, Plains Archaic (Old Copper), Middle Woodland (Laurel, Brainerd), Late Middle Woodland (Arvilla), and Late Woodland (Kathio, Clam River, Blackduck, Ogechie, and Sandy Lake). Also, the presence of the Woods Trail in the study area suggests a high likelihood of early historic sites such as Metis camps, bison kills, and homesteads.

3.12.3.6 Wheaton N

No sites recorded in the study area are found. However, both prehistoric and historic cultural resources are likely to be present. One prehistoric site (lithic scatters) and Tintah City (with recorded historic buildings) are located close to the study area.

3.12.3.7 Wheaton SE

One historic site and no prehistoric sites have been recorded in this study area. The historic site was not listed in the National Register of Historic Places. This area has not been surveyed, but its natural drainages indicate that prehistoric and additional historic sites probably exist.

One historic site, the Dollymount Town Hall, is just west of West Fork Creek. This building was constructed in about 1910 and was originally used as a school. Dollymount Township was organized in 1881 and named after the pioneer Anthony Doll.

3.12.3.8 Wheaton SW

The northwestern portion of the Wheaton SW study area bounds Lake Traverse crossing. The towns of Wheaton, Browns Valley, and Dumont have several recorded standing historic structures (Granger, 1985). Permanent settlements along Lake Traverse and Big Stone Lake were established in 1861-1872. In addition, fur trading in this area has been described as "immense" from 1867 to 1878 (Barrett, 1881). The trail bordering the northwestern portion of the study area, as well as fur posts such as the

one 5 miles southwest of the area, attest to the historic significance of the area. The trail that runs along the eastern shore of Lake Traverse and Mud Lake and abuts the Wheaton SW study area is a western extension of the larger Minnesota Valley Trail (Gilman et al., 1979). This western route was used during the first half of the nineteenth century.

The four prehistoric sites and two historic sites are recorded in the study area, but none are listed in the National Register of Historic Places. Because the Lake Traverse area has been used extensively by prehistoric and historic peoples, it is highly probable that additional prehistoric and historic sites are present in the study area.

Four prehistoric sites recorded in this study area are mounds. Round Mound (21TR1) is situated on the upland side southern outlet of the former glacial Lake Agassiz, now Big Stone and Traverse lakes. This site is 1.5 miles from the lake shore and about 1/2 mile from the bluff. Excavations were conducted in 1934 by Jenks (University of Minnesota). A preceramic habitation and three burial phases are suggested for this site. Occupations include early Archaic, Cambria, and Kathio affiliations (Wilford, 1970). A radiocarbon date of about A.D. 925 was secured for one of the occupations (Johnson, 1964b). Another mound (21TR21) was recorded by Lewis. Two other mounds (21TR22 and 21TR23) are also recorded (Winchell, 1911).

The William and Emilie Bartz farm, a historic site, was constructed in 1895. The farmhouse is one of the most ornate and most nearly intact farmhouses of this age in Traverse County. The other historic site is the Windsor Town Hall. This structure was built in about 1900 and was originally used as a town hall or school.

Another historic site, just outside the study area, is Maudada, a ghost town. The town was settled in 1881. Structures included a general merchandise store, flour mill, hotel, blacksmith shop, livery stable, and newspaper office. Eventually, the buildings were torn down or moved.

3.12.3.9 Amherst

State site files record one prehistoric site in this study area. No sites in the study area are listed in the National Register of Historic Places. No cultural resource surveys are known to have been conducted in, or within several miles of, this study area. However, several Paleo-Indian sites have been found in further outlying areas, and an examination of former glacial Lake Dakota shorelines, which transect the study area, might locate others.

One prehistoric site, 39ML40, is recorded on the south bank of a small stream that is a westward flowing tributary of the James River. The presence of this site has not been verified by a professional archaeologist. The record identifies 39ML40 as a campsite from which "many stone hammers and arrowheads" have been collected.

3.12.3.10 Grand Forks AFB

No cultural resource properties are recorded, nor has any cultural resources survey been performed at the proposed location for the CRS operations center.

3.13 Electromagnetic Environment

The electromagnetic environment at a particular location and time comprises all the electromagnetic fields arriving there from numerous sources, both man-made and natural. Some of these fields are used for communication or for radiolocation (radar). The electromagnetic environment in a given area can be described in terms of man's use of the electromagnetic spectrum there. The electromagnetic spectrum is a renewable resource with the dimensions of amplitude, time, frequency, and space. It can be used continuously. In areas large enough to permit sufficient geographic separation, the spectrum will accommodate a number of users on the same frequency simultaneously. In smaller areas the spectrum will accommodate a large number of simultaneous users only if they are using separate frequencies. A high-amplitude signal can mask a low-amplitude signal on the same frequency.

The electromagnetic environment at any point can change almost instantaneously and, at a given instant, it will not be the same at two points a few feet apart. Therefore, it is generally convenient to deal with averages over time and space. When there is sufficient incentive, certain features of the electromagnetic environment can be measured and documented. However, because of the cost, attempts are seldom, if ever, made to define the electromagnetic environment simultaneously over wide frequency ranges, large geographic areas, and long time durations. Most attempts at defining the spectrum are limited in scope, aimed only at providing answers to particular questions.

Some of the man-made contributions to the electromagnetic environment near the study areas are intentional, but others are accidental and are incidental to some other activity. Radio signals of all types are intentional man-made contributions. The electromagnetic environment in the area consists in part of signals from various broadcast radio and TV stations, from local or transient amateur and Citizens' Band (CB) operators, from air navigation aids, from passing aircraft, from satellites that provide cable TV programming, and so on. Because some signals, particularly those in the frequency range to be used by the CRS, can be reflected back to the earth at great distances by high-altitude ionospheric layers, part of the electromagnetic environment in the area consists of transmissions propagated from stations thousands of miles away.

Unintentional man-made contributions to the electromagnetic environment are called man-made electromagnetic noise. Such noise is radiated by power lines, fluorescent lights, household lighting dimmer switches, household appliance motors, computers, hand-held calculators, and so on. A major contributor is the automobile ignition system, which radiates a pulse of energy over all the communication bands with each spark-plug firing. Because the study areas are relatively remote from places with a large number of such noise sources, the man-made noise levels there are probably considerably lower than they would be in a city.

Nature contributes only noise to the electromagnetic environment, but it can contribute a great deal of it. Even when there are no local thunderstorms, lightning strokes in storm centers in Africa and South America can cause "static" in radios in the U.S. Midwest, thousands of miles away. Each lightning stroke acts as a powerful transmitter covering a wide frequency band. Its "signal" propagates to regions thousands of miles away. This noise is an intermittent major feature of the part of the electromagnetic spectrum to be used by the CRS. In the upper regions of this portion of the spectrum, noise from the sun and stars (galactic noise) is, in the absence of signals, the predominant feature of the local electromagnetic environment.

Human beings are not generally capable of sensing the electromagnetic environment or changes in it. However, radio receivers regularly do so. They sample portions of the spectrum to extract a small amount of energy, which they then amplify and convert to a usable signal. This signal might be in the form of a picture on TV channel 9 from Alexandria, music from KSL on 1160 kHz in Salt Lake City, a long-distance telephone conversation, an air navigation signal, or many others.

For man to make use of some portion of the electromagnetic environment for communication, radiolocation, radionavigation, or other such purposes, the power of the signal must exceed the power of the noise in that portion of the spectrum at the receiving location. For example, one cannot hear KSL's programming unless the power in the signal from the station is greater than the atmospheric noise and the man-made noise in the receiver's bandwidth. Thus, the electromagnetic environment is generally described by the presence of the man-made signals. Overall, the study areas have low signal power densities compared with a major metropolitan area.

Because the proposed action is the construction and operation of a large HF radar transmitter, the potentially affected environment extends far beyond the immediate study area, and at times might include almost any part of the world. The radar's sky wave may propagate by several hops so that it would be a feature of the electromagnetic environment in the HF band at locations far removed from the study area. Thus, for such a system, the environment includes much more than the immediate vicinity of the transmitter. The potentially affected environment actually extends to the HF spectrum in distant parts of the world.

4 ENVIRONMENTAL CONSEQUENCES

4.1 Introduction

This section describes the consequences or impacts on the environment of constructing and operating the CRS. The material is organized by topic in parallel to the environmental descriptions in Section 3. Mitigation measures to eliminate or reduce the environmental impacts are treated as part of each topic. As in Section 3, whenever possible, material is discussed at the regional or general level to avoid repeating material that applies to more than one study area.

The term "sector" refers to the antenna array, backscreen, groundscreen, support building, and excluded area associated with each 60°-arc of coverage (see Figure 2-3).

State and federal regulations pertaining to CRS environmental issues are presented in Appendix D.

Air Force policy is to recognize the significance of its actions on the environment where people live, work, or engage in recreational activities. The Air Force's goal is to ensure that its actions in the interests of defense intrude as little as possible while demonstrating responsible management of funds and equipment. Adoption of mitigation measures discussed in this section will be considered at the time of the decision whether to proceed with the proposed action or one of the alternatives. Measures suggested during the public review period will also be considered.

4.2 Land and Minerals

4.2.1 Overview

The geology and mineral resources of the study areas are generally very similar, and the impacts associated with the project would be similar. The principal difference in potential impacts among study areas is related to topographic relief and the resulting need for grading.

At all of the study areas, the bedrock is deeply buried and no effect on bedrock geology would occur. No mineral resources worthy of exploitation have been identified at any of the study areas. Construction of the radar would preclude any further surface exploration on the the sites, but because of the low value of the mineral resources that have been identified, this would not be a significant impact.

All nine study areas and the operations center site are located within Seismic Zone 1. Damage to structures resulting from an earthquake in Seismic Zone 1 is expected, on the basis of the history of events in the zone, to be minor (UBC, 1985).

Several study areas (Dahlen, Goose River, Galesburg, and Wheaton N) have soils classified by the Soil Conservation Service as corrosive to uncoated steel and concrete. This corrosivity could affect buried structures and objects, but would most likely not affect the groundscreen, which would be placed on the surface of the ground. Prior to construction at any of these areas, the severity of the corrosion potential would be investigated, and appropriate design measures such as coating or treating any exposed materials would be considered. The corrosivity should not present a significant engineering design problem, and it does not constitute an impact on the environment.

Construction of the operations center site would have little or no impact on geologic, mineral, or soil resources. The site is located in a flat, developed area of Grand Forks AFB. Construction activities would be limited to minor grading, paving of parking areas, and the erection of the operations center building. No significant erosion is expected. If the site has any mineral resources, they are not currently being exploited, and it is unlikely, in any event, that they would be exploited in the future given the site's location on the air base.

4.2.2 Topography and Erosion

Construction of the CRS transmit and receive sites would require a large cleared and graded area. At the receive site each antenna array and groundscreen sector would require an area approximately 10,000 ft long and 750 ft wide, with a 1% to 3% percent slope away from the antenna array. At the transmit site, each array and groundscreen require an area approximately 5,000 ft long and 750 ft wide with a 1% to 3% slope. In addition, at the transmit site, each sector would have an exclusion zone extending approximately 4,000 ft in front of the arrays that must be free of woody vegetation and cleared and graded to a lesser tolerance. Clearing and grading for roads, fences, and buildings would require approximately 25 acres. For all four sectors, total cleared area at the receive site and at the transmit site would be a minimum of 2,400 acres.

Because of the extensive clearing and grading requirements, the major differences in potential impacts among study areas are related to topography. Study areas with substantial topographic relief would allow less flexibility in locating the sectors, pose more difficulty in construction, and have greater potential for erosion. Less flexibility al;so might not allow adequate consideration of other environmental siting criteria, and greater construction difficulty would lead to higher costs. Erosion would produce environmental impacts beyond the loss of soil; these impacts are discussed in the sections on water resources, vegetation, and wildlife.

Erosion potential is also generally affected by the type of soil. All the study areas, with the exception of portions of the Amherst area, have erodable soils. The soils generally have a high fines content and are susceptible to erosion induced by water or wind, or both. However, the variability in erosion potential between study area soils is much less than the variation in grading requirements and does not substantially influence the amount of expected erosion.

Potential erosion can be reduced by approrriate design and mitigation techniques. Therefore, erosion control would be considered in the design of perimeter roads and drainage ditches and in the grading of slopes. Mitigation measures include good construction techniques and proper "housekeeping" during construction and operation; scheduling of construction activities to avoid or reduce exposed earth during periods of high erosion potential; specific erosion control techniques such as silt fencing, hay bales in drainage swales, wind breaks and water spraying during dry periods; and prompt revegetation of areas as work is finished.

To assess the amount of earth movement required for grading at each study area, and thus the potential for erosion, estimates were made of the amount of cut and fill needed to prepare for an acceptable radar site within each study area. Site locations were based on avoiding wetlands and areas of substantial topographic relief. The earth movement estimates were based on a balanced cut and fill with no imported materials, and were developed only for comparison purposes, not for design use. The results of the analyses are shown in Table 4-1.

TABLE 4-1

POTENTIAL FOR INCREASE IN EROSION

Study Areas	Potential
Receive Areas	
Dahlen	Significant
Goose River	Significant
Galesburg	Moderate
Blanchard	Slight
Thief River Falls	Slight
Transmit Areas	
Wheaton N	Slight
Wheaton SE	Slight
Wheaton SW	Slight
Amherst	Slight

Of the five receive study areas, Blanchard and Thief River Falls have sufficient flat area to locate the sectors without extensive grading. At these areas, less than 1 million cubic yards of earth, per sector on average, are likely to require moving. If appropriate mitigation measures were implemented, erosion would not significantly increase over current levels.

Topographic relief at the Galesburg receive study area is generally moderate. Grading at an acceptable location would require a considerable amount of earth moving, most likely 1 to 2 million cubic yards per sector. The potential for erosion would be substantial, and although mitigation measures would limit erosion, it would still most likely exceed current levels.

The Dahlen and Goose River receive study areas have more pronounced topographic relief than the other receive study areas. Substantial earth moving would be required for any location, most likely in excess of 2 million cubic yards per sector. In addition, the sectors might have to be substantially separated at the Dahlen study area. Erosion potential would be significant. Erosion control measures would reduce it, but substantial increases over current levels would occur.

The variation in necessary earth moving among the four transmit study areas is small. Because the transmit antenna arrays are shorter than the receive arrays, the groundscreens are smaller, and less land is required. All study areas are relatively flat and are likely to require that less than 1 million cubic yards of earth per sector be moved. If appropriate mitigation measures were implemented, no significant increase in erosion over current levels would be expected.

4.3 Water Resources

4.3.1 Overview

As in any construction project involving large amounts of earthwork, erosion and its effects on water quality are a major concern. Potential water quality impacts include higher concentrations of dissolved and suspended solids and greater siltation of stream beds. In addition, because eroded material from newly cleared land is generally much higher in nutrient content than that from land cleared earlier, greater nutrient loading and dissolved oxygen depletion may also occur. Proper handling of construction materials and the prompt revegetation of cleared areas would reduce erosion.

Small streams or drainage ditches crossing the site would be routed through buried pipelines or relocated. The site would then be leveled with fill. Burial of streams would not significantly alter the natural surface drainage pattern or the groundwater flow of the site. During construction, erosion would elevate dissolved and suspended solids concentrations in the water and increase siltation of downstream areas; however, erosion control measures could mitigate these impacts.

Because water would flow more quickly through the culverts than it had through the natural stream beds, the potential for downstream flooding would increase. This impact could be mitigated by constructing retention basins downstream from the culverted area to reduce the peak flood flow and allow the eroded material to settle. Applicable state, county, and local regulations for retention basins and the mitigation of flood impacts would be followed.

Wherever possible, sites would be selected to avoid interfering with major river courses. Diversion of a large surface water channel would entail filling the existing channel, excavating a new channel off the site, and grading the entire region so that runoff and the existing river flow would follow the newly constructed channel. Extensive impacts could be associated with such alterations. Heavy erosion could occur during construction and for several subsequent years. Erosion would increase dissolved and suspended solids in the water and increase siltation of downstream areas. Perennial rivers in this region are usually located in groundwater discharge areas. Relocation of a river channel would reroute the surface water flow, but discharges of groundwater in the filled natural channels might continue over time. Consequently, it would be necessary to fill the channel with permeable material to allow the groundwater to flow along its natural course. Thus, both the surface and subsurface flow patterns would be altered.. No mitigation has been presented for the diversion of rivers because this activity would be avoided through site selection. Streams and lesser flows would be treated appropriately if diversion is required.

Small ponds or wetlands would be filled, resulting in an increase in surface runoff because there would be no basins to retain the water. Such filling could significantly alter the natural drainage pattern of an area and result in increased downstream flooding. To mitigate this impact, perimeter drainage ditches would be constructed as required to collect and channel the runoff from the site to the natural drainage channels. Prior to being discharged into the natural channels, drainage flow could be routed into retention ponds, if necessary, to reduce the peak flood flow to downstream areas.

Potential impacts on groundwater resources include contamination of near-surface aquifers by spills of oil or gasoline during construction, by leaks from underground fuel storage tanks during operation, and by interference by the shallow antenna foundations with the groundwater system. Caution would be used in handling fuel supplies, and absorptive materials would be kept ready to expedite clean up if a spill were to occur.

At both the transmit and receive sites, approximately 36,000 gallons of fuel would be stored. Because the unconfined glacial till aquifers in this region are extensively used, spils or leaks are a concern. Design and construction of fuel storage tanks would take into consideration the corrosivity of the groundwater and the fluctuating high water table to provide adequate protection of near-surface aquifers.

For underground tanks, the corrosivity of the soil and groundwater may require the use of either fiberglass reinforced plastic tanks or cathodically protected steel tanks. All applicable federal, state, and local regulations for the design and construction of underground fuel tanks would be followed. If above-ground storage tanks are used, they would be located in an earth-bermed area over an impermeable liner capable of containing more than 150% of the amount of fuel stored. An in-tank inventory and monitoring program would be established to detect an abnormal drop in fuel level. An emergency action plan would be developed prior to the construction of the facility. The plan would describe procedures to minimize contamination from any spill or leak.

These protections would be incorporated into a Spill Prevention Control and Countermeasure Plan (SPCCP). The plan would conform to EPA requirements and Air Force regulations (AFRs) that apply to fuel use, including AFR 19-7 ("Environmental Pollution Monitoring"), AFR 19-1 ("Pollution Abatement and Environmental Quality"), and AFR 19-8 ("Environmental Protection Committees and Environmental Reporting").

Seasonal high groundwater ranges from 7-8 ft to 1-3 ft below ground surface in the study areas. In the selected site areas, the actual depth to groundwater would be determined prior to construction. Deep groundwater is preferred to minimize interference by the shallow (4-5 ft) antenna foundations with the local groundwater system. Foundations may have to be constructed during the late summer when groundwater is at its maximum depth.

Both the transmit and receive sites would require domestic water supply and wastewater disposal facilities for up to 36 persons (the total 24-hr staff). Assuming average domestic water use of 30 gpd per person a water supply of 1,100 gpd would be required for the operation of these facilities. A well yielding less than 10 gpm would be sufficient to meet this requirement. Yields of this magnitude can most likely be obtained from wells to the glacial till within any of the study areas. Most of the homes located in the study areas rely on individual wells for their domestic supplies. After sites were selected for the CRS, homes would be relocated, and their wells would probably be closed. Because CRS domestic water requirements wuld be similar to current use, the amount ot vater being withdrawn from the site would generally not increase. Consequently, the effect of this water withdrawal on the local groundwater system should be negligible.

Assuming that 90% of the water used at the sites becomes wastewater, facilities capable of treating approximately 1,000 gpd of domestic sewage would be required at each site. A lagoon similar to but smaller than ones located in Fordville and Galesburg, North Dakota and in Langford and Pierpont, South Dakota, could be constructed. Because the Air Force would be required to follow all applicable state, county, and local regulations for the design and construction of an appropriate

facility, wastewater disposal at the transmit and receive sites should not have a significant impact on the water quality. During construction, the system contractor would be required to provide water and wastewater facilities conforming to applicable federal, state, and local regulations.

Table 4-2 presents a summary of the surface water resources located within each study area and indicates those resources that would be affected. As indicated in the table, impacts on the major surface water resources could be completely avoided in the Blanchard, Thief River Falls, and Amherst study areas. In the Wheaton N and Wheaton SE study areas, relatively few water resources would be affected.

4.3.2 Study Areas

4.3.2.1 Dahlen

In the Dahlen study area, the alteration of numerous surface water features cannot be avoided. Nearly all sections contain small transient streams; densities range from one to two streams per square mile in the north to as many as eight streams per square mile in the south. Major surface water channels within the study area include the Middle and South Branches of the Forest River and the Skunk Coulee. The Matecjek Dam, a flood control impoundment of the Middle Branch of the Forest River, and several temporary ponds and wetlands are also located in this area.

The extensive grading and clearing required to alter these drainage channels and construct the receive site within the Dahlen study area would cause large amounts of erosion and subsequent impacts on water quality. Although the construction of retention ponds, proper handling of construction materials, and prompt revegetation of the cleared areas would decrease the amount of erosion, impacts on the water quality of the area would still be substantial.

4.3.2.2 Goose River

The numerous surface water bodies located within the Goose River study area could not be avoided in constructing the receive site. The eastern sections contain the most numerous water resources, so the radar facilities would probably be located in the drier western sections. Only one intermittent creek, Goose Creek, flows through the western sections.

If the site was located in the western sections, impacts would be moderate. The lakes and sloughs along the southern border could be avoided. Goose Creek would be either culverted or diverted, and only small amounts of grading would be required. Impacts associated with grading, clearing, and culverting of the stream would include increased erosion and its impact on the water quality.

Table 4-2

POTENTIALLY AFFECTED WATER RESOURCES

Study Area	Streams, Drainage Ditches	Rivers	Perennial Ponds, Impoundments	Temporary Ponds, Wetlands[3]
Dahlen	Numerous[1] Unavoidable[2]	Few Avoidable	Few Avoidable	Few Avoidable
Goose River	Numerous Unavoidable	Few Avoidable	Several Avoidable	Numerous Avoidable
Galesburg	Numerous Avoidable	Few Avoidable	Few Avoidable	Numerous Unavoidable
Blanchard	Several Avoidable	Few Avoidable	None	None
Thief River Falls	Several Avoidable	None	Few Avoidable	Numerous Avoidable
Wheaton N	Few Unavoidable	None	None	None
Wheaton SE	Few Unavoidable	None	None	None
Wheaton SW	Several Unavoidable	None	None	Numerous Unavoidable
Amherst	Several Avoidable	None	Few Avoidable	Numerous

[1]"Numerous" indicates more than 15 items in entire study area; "several" indicates between 5 and 15 items in entire study area; "few" indicates less than 5 items in entire study area.

[2]"Avoidable" is used to indicate whether the features could be avoided if the facility is optimally located; "unavoidable" indicates that at least one of the features would be affected for the site.

[3]As shown in USGS maps.

4.3.2.3 Galesburg

Numerous small ephemeral ponds and marshes lie within the Galesburg study area. The central sections are nearly covered with small, transient ponds with densities in excess of 30 ponds per square mile. These ponds are less common in the northern and southern sections of the study area. Although northern sections 10 through 16 and 21 through 23 of T. 145 N., R. 54 W., are relatively dry and flat, the area is not large enough for all four CRS sectors. Filling some of the ponds immediately south would be required to place the site in this area. Furthermore, although the hilly southern sections contain fewer ponds, the area would require extensive grading. This area also drains into numerous small transient streams and the Elm River and would most likely be avoided because extensive grading would be required.

The extensive grading, earth movement, alterations to drainage channels and filling of ponds that would be required to construct the receive site in the Galesburg study area would result in significant impacts on the water quality.

4.3.2.4 Blanchard

Other than the sections crossed by the various branches of the Elm River, the Blanchard study area is devoid of surface water features. The majority of the sections in the study area are very flat and would not require grading or alteration of the drainage pattern of the area. The sections that contain the channels of North and South Branches or the main stem of the Elm River would be avoided.

Because grading, earth movement, and alteration of the drainage pattern required to construct the receive site in most sections of the Blanchard study area would be minimal, impacts on water quality would be negligible. Some minor erosion would occur during and after construction.

4.3.2.5 Thief River Falls

The Thief River Falls study area contains both dry flat sections and sections with numerous large swamps and marshes, state-protected drainage ditches, and the headwaters of the Black River, also a state-protected water course. Because the majority of these water resources are located in the eastern sections of the study area, the receive site would most likely be located in the dry, flat western sections.

Constructing the receive site in the western sections that do not have surface water bodies would not affect the natural drainage pattern of the area. Because constructing the receive site in this flat area would involve little grading as well as no alteration to the natural drainage pattern, impacts on water quality would be negligible.

4.3.2.6 Wheaton N

Other than relatively small county drainage ditches, the Wheaton N study area lacks surface water bodies. All area sections are extremely flat and would not require extensive grading or alteration of the natural drainage pattern. If the sections containing the county drainage ditches were selected for the transmit site, the ditches would be culverted. In Sections 29, 32, and 33 of T. 129 N., R. 45 W., drainage ditch No. 11 is classified as a state-protected water course, subject to Minnesota Statutes Section 105.42, which requires that a permit be obtained before making any alteration to the course, current, or cross-section. Because alteration of the existing area drainage channels would be minimal, perimeter ditches would not be required, and impacts on the hydrology and water quality of the area would be minimal.

4.3.2.7 Wheaton SE

The Wheaton SE study area is crossed by the east and west forks and the main stem of Twelvemile Creek. The area has no other surface water. The majority of the sections are very flat and would not require extensive grading or drainage alterations. Because it is impossible to locate the transmit site to avoid the sections that are crossed by Twelvemile Creek or its branches, the creek channel would be culverted or diverted as described in Section 4.3.1. Because all these branches have been designated as state-protected water courses, a permit would be required to make these changes. Because minimal grading and relatively minor alterations to the drainage pattern would be required, impacts on water quality would be small.

4.3.2.8 Wheaton SW

Several small, unnamed transient streams and drainage ditches, most of which are state-protected waters, flow through the Wheaton SW study area. All drainage from this area flows directly into Traverse Lake, which now supports commercial fishing and recreation. The eastern sections also contain a large marsh and several small transient ponds.

Construction of the site facility would require the filling of all ponds and wetlands and the culverting of all streams and drainage ditches within the site. Because most sections contain at least one surface water feature, alteration of the natural drainage pattern would result. Most sections would require some grading to promote runoff from the site. The clearing, grading, and culverting of streams would directly affect the quality of Lake Traverse. Elevated concentrations of dissolved and suspended solids and nutrients would increase siltation, eutrophication, and the dissolved oxygen depletion of the lake. Perimeter drains and retention basins would reduce the impact of the runoff on the lake.

4.3.2.9 <u>Amherst</u>

The Amherst study area has no major surface water features. The northern sections, which are intersected by the Crow Creek drainage ditch that empties into Renzienhausen Slough, should be avoided.

Small streams and drainage ditches located within the transmit site would be culverted. Because most of the sections are flat and well drained, the existing hydrologic conditions would be altered only slightly, and impacts on the water quality would be negligible.

4.3.2.10 <u>Grand Forks AFB</u>

Because no surface water features are located on the site, diversion of surface water would not be required. But water would be required on base for construction and domestic use during construction and for the additional personnel that would staff the operations center during operation.

During construction, approximately 75 workers would be on site: they would need approximately 30 gpd of water per person. An additional 2,000 gpd would be required for use in construction. Grand Forks AFB has indicated that hydrant water cannot be used to supply this construction water. During operation, 27,300 gpd would be required for domestic use by the 390 staff members who would work at the center. The water supply on the base is sufficient to meet all of these additional requirements.

Assuming that 90% of the additional water for the operations center becomes wastewater, approximately 3,800 gpd of wastewater would be generated during construction, and 24,600 gpd would be generated during operation. Existing sewage lagoons could handle this increase in wastewater volume.

Drainage from the parking lot and gutters on the site would be directed into the existing storm drainage system. A 72 inch reinforced-concrete pipe is located on First Avenue, approximately 600 ft south of the proposed site.

Because storm runoff from the site would also be directed into the existing storm drainage system, the additional runoff from the site parking lot should have a negligible effect on the regional surface and subsurface water quality.

4.4 <u>Vegetation</u>

4.4.1 <u>Overview</u>

The CRS would have very little effect on natural vegetation other than wetlands at any of the study areas because the native prairie grassland has been replaced by agricultural crops and very small stands of trees planted as shelter belts. The principal natural vegetation

subject to impact would be wetland vegetation. Because their occurrence varies greatly among sites, the impacts at each site are largely dependent on the amount of wetlands it has. Wetlands would be avoided whenever their density and location permits. If necessary to construct an antenna array, groundscreen, road, or building, wetlands would be filled to the same level as the surrounding land. In unpaved areas, wetland vegetation would be replaced with grasses or other low-growing herbaceous species. If it is necessary to channelize a stream, the amount of stream-associated wetland in the channelized portion would be diminished.

Other impacts on wetlands could result from constructing access roads across streams or from runoff and erosion from construction areas.

At most sites, construction of a sector would eliminate several shelterbelts that surround farmhouses or border fields. Site development could result in an increase in natural vegetation over that found at present if land removed from agricultural production is revegetated with native grasses or other natural habitat.

4.4.2 Mitigation

Possible mitigation measures include the following:

- Locate facilities to avoid wetlands, shelter belts, and trees to the greatest extent possible. When conflicts between these goals arise, avoidance of wetlands would take precedence over avoidance of trees. Because wildlife is closely associated with vegetation, additional mitigation measures affecting vegetation are found in Section 4.5.2.

- Survey the area for endangered, threatened, and other state and federal plant species of special concern, and site facilities to minimize damage to any such plant species. If it was determined that the project may affect federally listed species, formal consultation for compliance with Section 7(c) of the Endangered Species Act of 1973 would be requested from the U.S. Fish and Wildlife Service.

- Locate access roads, buildings, and other facilities to make maximum use of existing roads and other disturbed areas.

- If a site must be graded, take precautions to avoid erosion and runoff into nearby streams and wetlands. Precautions could include ditching to divert runoff, hay bales, silt fences, and erosion control and revegetation mats.

- Survey and map areas of wetland vegetation that would be unavoidably affected by the project. Surveys would include identification of all plant species and notation of their condition and habitat value. Areas outside the facilities, exclusion fences, and any other disturbed areas could be

surveyed to identify locations where existing wetlands could be expanded or new wetlands could be created. These areas could be excavated to create wetlands similar in size, water regime, and vegetation to those filled or otherwise destroyed by project construction. The wetlands could be planted with native vegetation of species to be determined by a survey of previous wetlands and reference to Stewart and Kantrud (1971 and 1972). New wetlands should be situated so that the primary migratory routes of waterfowl do not carry them over the antenna arrays.

4.4.3 Study Areas

The following assessments of impacts on wildlife habitat is based on the assumption that, within each study area, the sectors would be placed where they would have the location of least impact on wetlands.

Blanchard would suffer the smallest impact on wildlife habitat of any of the receive sites. It has very few wetlands in its south-central part, few wooded areas, and no extensive wetlands situated so that waterfowl would fly near the site. The northwestern corner of Thief River Falls is also an area where little direct impact on wetlands would occur. However, the extensive wetlands of Goose Lake Swamp, about 5 miles southeast of this corner, are an important waterfowl area. Dahlen, Goose River, and Galesburg all have numerous stream-associated wetlands, at least some of which could not be avoided. Even larger important wetlands are nearby.

Among the transmit study areas, development of Wheaton N would have the least ecological effect on vegetation and associated wildlife. Some temporary wetlands, but no permanent ones would be affected, and no significant wetlands are nearby. A sector in the central portion of the Amherst study area would directly affect few natural areas. However, although it would not be in a major migratory pathway, wetlands important to waterfowl are located both north and south of such a site. A sector at Wheaton SE would unavoidably affect wetlands associated with one or more streams. At Wheaton SW, a sector would cause the loss of numerous temporary pothole wetlands, and would be on the route of waterfowl flying between Traverse Lake and Mud Lake and wetlands in and south of the study area.

The impacts at each study area are summarized in Table 4-3. The habitat analysis was generally based on a review of available maps and aerial photographs taken in the spring.

4.4.3.1 Dahlen

Stream-associated wetlands are very numerous in this study area, and several intermittent streams would have to be crossed. In the northern part of the area, a sector would come within a mile of the reservoir on the Middle Branch of the Forest River and its associated downstream wetlands; it would eliminate several small wetlands and would require modification of at least two intermittent tributaries.

Table 4-3

AFFECTED WILDLIFE HABITAT*

Study Area	Pothole Wetlands	Stream-Assoc. Wetlands	Wooded Areas	Nearby Waterfowl Habitat
Dahlen	Few Unavoidable	Many Unavoidable	Numerous Unavoidable	Common
Goose River	Numerous Unavoidable	Several Unavoidable	Few in West Unavoidable	Abundant
Galesburg	Abundant Unavoidable	Several Unavoidable	Numerous Unavoidable	Abundant
Blanchard	Few Unavoidable	Several Unavoidable	Few Unavoidable	Very little
Thief River Falls	Few Unavoidable	Numerous Avoidable	Few Unavoidable	Abundant
Wheaton N	Few Unavoidable	None	Few Unavoidable	Little
Wheaton SE	Few Unavoidable	Several Avoidable	Few Unavoidable	Little
Wheaton SW	Numerous Unavoidable	Few Unavoidable	Few Unavoidable	Abundant
Amherst	Few Unavoidable	Numerous Avoidable	Few Unavoidable	Abundant

*By a site located in the least critical part of each study area.

In the southern part of the area, intermittent streams are even more numerous, and the emergent wetland vegetation associated with at least 10 such streams, totaling several miles in length, would be destroyed. In addition, the riparian deciduous trees and shrubs along Skunk Coulee would be destroyed.

4.4.3.2 Goose River

A receive sector in this area would cover an area now occupied by approximately 40 palustrine emergent temporary wetlands, even in sections where wetlands are least dense. Siting is limited in the western part of the area by the need to avoid Rugh Lake, Horseshoe Lake, Matson Slough, and Goose Creek, and the emergent wetlands associated with them. Goose River and Little Goose River similarly restrict siting in the north-central and northwestern parts of the site. These and other small tributaries are surrounded by emergent wetlands approximately 200 ft across.

Impacts in the southern part of the area would be similar to those in the north. Any sector would affect 5 to 10 intermittent streams, numerous emergent pothole wetlands, and several shelter belts.

4.4.3.3 Galesburg

Prairie potholes and their associated palustrine emergent vegetation are numerous throughout this area. A receive sector could affect as many as 100 individual temporary pothole wetlands. Although wetlands are concentrated most heavily in the central part of this area, they are found throughout it. In addition, the site could affect the stream-associated emergent wetlands along the South Branch of the Goose River in the northern part of the study area, the Elm River in the central part of the study area, and several intermittent streams to the south, all with associated emergent vegetation.

4.4.3.4 Blanchard

This area has the smallest proportion of habitat types other than cropland of any of the receive study areas. The principal wetlands in the area are the emergent wetlands about 200 to 300 yards wide associated with the Elm River and its North Branch, which extend across the northern part of the study area. A sector could be located in the south-central portion of this study area without requiring diversion of one of these rivers and affecting stream-associated wetlands; that location would also avoid some temporary streams to the east and a small concentration of potholes to the west.

4.4.3.5 Thief River Falls

A receive sector in the eastern part of this study area would eliminate a large area of woodland, probably as much as 25% of the area, or about 230 acres. Substantial permanent emergent wetlands, 0.5 square mile or more in area, are found across the southern part of the study area. Some wetland area would probably be eliminated by a sector in these areas. In the northernmost and westernmost parts of the study area a sector could be located without impact on a significant wetland or more than a few small isolated stands of trees.

4.4.3.6 Wheaton N

A transmit site in this area would affect very little except croplands. The area has virtually no permanent wetlands, although small areas of emergent plants may exist around drainage ditches. Numerous temporary wetlands form on this flat terrain, and the site would eliminate some of these, together with their emergent wetland vegetation.

4.4.3.7 Wheaton SE

The chief vegetational feature affected by a transmit site in this area would be the emergent wetlands associated with Twelvemile Creek and its tributaries, the East Fork and West Fork. Four antenna arrays and their associated cleared areas in this study area would necessitate modifying one or more of these streams, and loss of any associated wetland.

4.4.3.8 Wheaton SW

The principal nonagricultural vegetation of this study area is emergent macrophytes associated with the many temporary wetlands of the area. A total of 40 such pothole wetlands could be eliminated by construction of a transmit site in this area.

Two state special-status species, the special-concern Missouri milk vetch and the endangered Wolf's spike rush, have been found on the hill prairies overlooking Lake Traverse in the northwestern part of the study area. The siting of any facility in this region would require a careful search for such protected species.

4.4.3.9 Amherst

The majority of the vegetation affected by a transmit site in this study area consists of agricultural crops. Other vegetation includes emergent wetlands associated with Renzienhausen Slough and Crow Creek in the northern part of the study area, and numerous shelter belts in the north-central part. The southern part of the area has a medium to high density of emergent wetland vegetation associated with intermittent streams.

Depending on the location within the study area, the transmit site could remove either substantial amounts of wetland vegetation at each antenna site or several large shelter belts and smaller amounts of wetland at each site.

4.5 Wildlife

4.5.1 Overview

Construction of the CRS would involve clearing and leveling four large areas of land. These areas would be close to one another, but

need not be contiguous. A wooden exclusion fence 8 ft high made of 2-inch wide wooden slats with 6-inch spaces between them would surround each sector.

Potential impacts on wildlife are of four types: (1) impacts on terrestrial animals caused by changes in the existing vegetation and associated habitats; (2) limitations on animal movement; (3) impacts on wetland-dependent animals, principally birds; and (4) RFR effects on small animals. Communications from the U.S. Fish and Wildlife Service (USFWS) on the effects of the proposed project on wildlife (Collins, 1986; Keenlyne, 1986; Welford, 1986) have emphasized potential impacts on birds, from both collisions with the antennas destruction of wetland habitat. Even within the exclusion fence, no significant impacts on small animals are expected (see Section 4.14.3.10).

4.5.2 Habitat-Related Impacts

The exclusion fences would prevent large mammals from entering the areas in front of the antenna arrays, and therefore would remove a substantial amount of habitat. Each exclusion fence would be placed far enough from the transmit array antenna to avoid harm from radiofrequency radiation (RFR) to humans or wildlife outside the fence. Small mammals would be able to pass through the fence.

Impacts on mammals would depend on the type of habitat that is eliminated. If trees and shrubs in shelter belts were removed, animals dependent on wooded habitat would be displaced. These include raccoon, gray fox, pygmy shrew, short-tailed shrew, eastern cottontail, European rabbit, snowshoe hare, white-footed mouse, and southern red-backed vole (Whitaker, 1980). Other small mammals, generally associated with more open, grassy areas, would be less affected by the project. Site land not built on could be enhanced as habitat for many small mammals because cultivation would be replaced by grasses and the area would remain continuously vegetated.

The movements of large mammals would be restricted by the exclusion fences, and they would be excluded from 2,400 acres at either the transmit and receive sites. Moose, elk, and white-tailed deer are the three large mammal species that may be found in the study areas. Moose and especially elk are very rare in this region and are most likely to be found only in the more northern areas. Deer are found throughout the area, especially in the more varied habitats where deciduous forested areas alternate with fields and wetlands. Because none of these large animals follows a regular migratory route, restriction of their movements should not seriously affect the populations, although they may be somewhat impeded in their search for food.

Increased human activity in the area, especially during construction, could disturb wildlife. During operation, however, human activity should not differ greatly from that associated with farming at present.

The greatest disturbance to wildlife habitat would come from the destruction of wetlands. As discussed previously, some water-dependent mammals, reptiles, amphibians, and birds would be displaced or eliminated by this action. Some breeding habitat, feeding and resting areas, and food supply for migrating waterfowl would be lost.

4.5.2.1 Mitigation

Several measures may be taken to reduce the impacts on wildlife. The most effective measure is to select a study area and site that avoid sensitive wildlife habitats, such as wetlands, rivers, and shelterbelts, as much as possible. If it is not possible to avoid such habitats, action could be taken to mitigate habitat loss as much as possible. Efforts to reduce wildlife impacts during construction and operation would also be made. The following is a discussion of these possible measures.

4.5.2.1.1 Study Area Selection

The most important criterion for selecting a site so as to minimize environmental impacts is avoidance of sensitive habitats. Sensitive habitats include wetlands, shelter belts, and rivers and streams, all of which provide valuable wildlife feeding, breeding, and resting areas. Endangered, threatened, and other state and federal species of special concern, if they occur, are also likely to be found in sensitive habitats.

4.5.2.1.2 Site Selection

Once a study area has been selected, specific sites for the sectors would be selected. If a field survey of the sites determined that the project might affect federally listed endangered or threatened species, formal consultation to comply with Section 7(c) of the Endangered Species Act of 1973 would be requested from the USFWS. Additional studies would be conducted, if necessary, to determine exactly where sensitive habitats are located within the study area. If significant habitats cannot be avoided, the resource would be evaluated and actions taken to mitigate the loss of habitat as much as possible.

If a site that avoids wetlands cannot be found the value of the affected wetlands would be determined and possible mitigation measures would be defined. All wetland vegetation that is unavoidably affected by the CRS would be carefully surveyed and mapped. Plant species would be identified, and their condition and habitat value noted. If required, areas immediately adjacent to the proposed facilities might also be surveyed to identify locations where existing wetlands could be expanded or enhanced or new wetlands created to replace those taken. If wetlands replacement is necessary to mitigate the impacts, a typical approach is the USFWS Habitat Evaluation Procedure (USFWS, 1985). Briefly, this consists of the following:

1. Map the project areas and an approximately equal area of adjacent habitat that could be used for mitigation to determine the amount of each land use/cover type present (e.g., the areas of agricultural cropland, deciduous forest land, and palustrine emergent wetland).

2. Within each of these cover types, determine its suitability as habitat for certain key species known to inhabit the area through use of a Habitat Suitability Index developed for each species.

3. Develop a value for the composite suitability of the habitat to be lost and determine the potential for improving nearby, unaffected habitat to compensate for the loss. Plans for mitigation of habitat losses would then be formulated.

If it is determined that new wetlands are to be created, attempts would be made to situate the new wetlands such that the primary local migratory routes of waterfowl do not carry them over the antenna arrays as they fly between habitats.

If the location of the site made it necessary to divert a stream or river the new channel would be designed with the goal of making its associated wetlands of equal or greater value than those impacted. This would be done by using proper slopes and gradients for the stream banks. If it was necessary to culvert a stream, the goal would be to create new wetlands of equal or greater value in the vicinity. If a retention pond is necessary to control flooding during high flows, it would be designed so that its associated wetland would provide valuable wildlife habitat, if possible.

4.5.2.1.3 Construction Mitigation

An important mitigation measure is to locate access roads, buildings, and other facilities to make maximum use of existing roads and other disturbed areas. This would preserve undisturbed areas. Vehicular travel could be restricted on the parts of the site not needed for access to the construction site.

The seasonal timing of the land clearing will influence impact on wildlife. Spring is the most sensitive time of year for most wildlife because it is when they breed. Summer is also a sensitive time because animals are very active and feeding on summer vegetation. Wildlife are least active in winter when food supply is low. The best time to clear land would likely be in winter or fall when fewer animals would be in the area and their breeding cycle would not be impaired. The Air Force will consider clearing land at the time of year when wildlife will be least impacted.

If feasible, temporarily disturbed sites not needed for project operation would be rehabilitated to compensate in part for permanent loss of wildlife habitat. The ground surface would be restored to its original contour where feasible and be revegetated with seed mixes and general procedures recommended by the USFWS.

Where grading was necessary, measures to minimize impacts on nearby streams and wetlands would be taken. Erosion from grading activity would be reduced by using erosion control measures such as ditching, runoff, hay bales, silt fences, and erosion control and revegetation mats.

4.5.3 Bird Collisions

4.5.3.1 General Background

The potential for bird collisions with the CRS antenna arrays depends primarily on the biology of the species, environmental conditions, and the structure and location of the arrays. SRI International (1986) conducted an extensive review of the literature concerning these factors as they relate to bird collisions. The following is a summary of SRI's findings that are relevant to this project.

4.5.3.1.1 Influences of Bird Biology

Certain species of birds are more vulnerable to collisions than others because of species-specific behavior or other biological factors. Factors such as migration patterns, time of movement, flight patterns, response to light, and the condition of individual birds contribute to a species' susceptibility to collisions with man-made structures.

Migratory birds (such as those associated with the Central Flyway) are generally more susceptible to collisions with man-made structures than local bird populations (such as red-winged and yellow-headed blackbirds associated with wetlands in the project region). Local or resident birds are more familiar with the area and adapt to the presence of structures; migratory birds lack this familiarity and, therefore, are more likely to collide with structures when flying between feeding, roosting and breeding areas. Because of the large number of migratory birds in the project region, the project may have negative impacts on migrants at some of the study areas.

Migrating birds travel at relatively high altitudes under normal environmental conditions and do not usually collide with relatively short structures. A study of migration altitudes conducted in spring 1967 in New Orleans found that 70% of birds migrating at night were between 800 and 3,700 ft in altitude, and that within this zone, approximately 75% of the migrants were between 800 and 1,600 ft in altitude (Gauthreaux, 1978). Birds that migrate in the daytime generally do so

at altitudes somewhat lower than those favored by night migrants--usually at altitudes below 1,000 ft. There is little likelihood (except under adverse environmental conditions) that birds in migratory flight would encounter one of the CRS arrays, which range from 35 to 135 feet in height.

Flight characteristics also influence a bird's susceptibility to collisions with man-made structures and wires. Birds such as teal and diving ducks are vulnerable to collisions because of their high-speed, low-altitude flights. Teal usually fly only a few feet above the ground upon leaving a water body. Mallards fly higher than teals and are therefore less susceptible to collision. Generally speaking, "the larger the bird species and the faster its air speed, the higher it flies during migration" (Gauthreaux, 1978) and therefore the lower its risk of collision. The activity cycles of each species also determine flight altitude and influence collision potential. Take-off and landing are critical periods because birds are flying lower and are in transition between flight and nonflight. Local and migrant waterfowl have greater susceptibility near or over a water body because that is where they takeoff and land.

Birds' response to lights on a structure may also influence their susceptibility to collisions. For example, warblers appear to be attracted to red tower lights. According to Avery et al (1975), at the 1,200 ft Omega tower in North Dakota, many more warblers collided with the tower itself, which has red tower lights, than collided with the outlying system of guy wires. This finding seems to indicate that the birds were attracted to the lights on the tower. Experiments have shown that a nonflashing light attracts birds more than a flashing light (Jaroslow, 1979). Birds are particularly attracted to lights on overcast nights. An explanation may be that the birds use celestial navigation, and on overcast nights, their orienting star is lost to them because a light atop structure becomes much more visible when reflected by the water droplets in the air.

Biological attributes of individual birds, such as maturity, may have some significance in vulnerability to collisions. Several studies have reported a higher frequency of kills among inexperienced, immature birds. Crawford (1978) reported that 54% of 3,149 birds killed at a 1,010 ft tower in Florida during the autumns of 1973-1975 were immature. Therefore, the large number of immature birds that migrate through the project region in the fall following spring breeding have greater susceptibility to collisions.

Birds involved in aerial chases or courtship displays also appear to be more susceptible to collisions. This susceptibility results from the erratic flights and inattentiveness birds display when pursuing prey, defending a territory, or pursuing females in nuptial flights.

Injured birds or those in poor health also have greater susceptibility to strikes. Several species of migratory waterfowl, including mallards and teals, as well as local bird populations, breed in the study areas. These birds may be more susceptible to collisions during spring courtship displays.

4.5.3.1.2 Influence of Environmental Conditions

Environmental conditions influence a bird's flight pattern, and therefore its potential for collision with structures. Windstorms, rainstorms, fog, and other meterological phenomena that reduce visibility or cause birds to fly lower increase the susceptibility of birds to collisions. Human disturbance may also contribute to collisions by startling birds and causing them to fly into structures.

Waterfowl and other birds reduce their altitudes to near ground level when flying into strong winds (Krapu, 1974) and therefore increase their likelihood of striking man-made objects. Overcast weather conditions also influence a bird's flight behavior and therefore its susceptibility to collisions. Some birds fly under an overcast, even within a few meters of the ground on misty, cloudy nights (Gauthreaux, 1978), and others fly above it. Birds flying under a low cloud cover are more likely to encounter a structure than those flying above the overcast. Numerous bird collisions are often preceded by the passage of a cold front, which is often accompanied by overcast or rain, a drop in temperature, or a change in wind. Fog is also potentially hazardous because flying birds may become disoriented and mill about, increasing the probability of collision. Adverse weather conditions such as windstorms, overcast skies, and fog occur in the project region, especially in the spring and fall. More bird collisions would probably occur at the CRS sites during these times.

Generally speaking, weather conditions that increase the potential for bird collisions are not conducive to large migratory movements; however, birds might begin a migratory flight under ideal conditions and move into areas of unfavorable weather. According to Gauthreaux (1978), 50 to 60% of the night-to-night variation in the quantity of migration is explained by weather, and "the remaining variation is undoubtedly due to the internal conditions of the migrants (energy, physiological readiness) and the number of ground migrants in the area."

Although weather can contribute to bird kills by affecting migratory behavior, collisions can occur on clear nights with excellent visibility. An atmospheric temperature inversion that has produced a low-level jet stream may explain these rare occurrences. Migratory birds "may descend to take advantage of the tail wind and large numbers can collide with obstacles (Jaroslow, 1979). A 2-year study conducted at the Omega tower in North Dakota (Avery et al., 1977) reports that mortality occurred consistently under clear as well as overcast conditions. In spring, kills occurred on nonovercast nights with favorable southeasterly winds. This type of wind pattern occurs in the project region, and might lead to more bird collisions.

There appear to be fewer collisions in spring than in fall (McDonald, 1979). A study conducted at seven sites in North Dakota between 1980 and 1982 by Faanes (1984) reported that 81% of the total bird mortality occurred during fall migration. The study at the Omega tower in North Dakota (Avery et al., 1977) reported that the spring kills were smaller and more evenly distributed than the fall kills. Possible reasons for this may be the larger concentration of immature birds in the fall and behavioral differences among migrant species.

Human disturbance may also contribute to bird collisions in areas where wires or structures are close to bird use areas. Hunting activities, airplanes, and passing vehicles startle and disturb birds, flush them from fields or roosting areas, and promote collisions.

4.5.3.1.3 Structure Design and Location

The height of a structure influences potential bird collisions because the taller a structure is, the more likely a bird is to encounter it. Structures involved in bird collisions range in height from less than 100 ft to more than 2,000 ft. Although numerous bird collisions with structures between 100 and 400 ft have been reported, collisions in general appear to be more common at taller structures (Avery et al., 1977). Because all structures for the CRS would be less than 135 ft tall, height will probably not be a major issue influencing collisions. Other structural characteristics of the CRS, such as the backscreen mesh and the length of the antenna arrays, are likely to be more important factors.

Wires and cables raise the potential for collision. For example, the Omega tower in North Dakota reports a high level of avian mortality because of its elaborate system of cables. Birds cannot see such wires and cables in time to avoid them. Losses occur at other towers with less extensive cable systems, but the kills are not as large as those at the 1,200-ft Omega Tower (Avery et al., 1977). The CRS structures would not have guy wires like those at the Omega tower. However, they would have a backscreen comprised of wires; these would be much lower than most guy wires, but they will be virtually impossible for birds to pass through without collision.

The location of structures is also an important factor in the potential collision hazard to migratory birds. Collisions most frequently occur where structures or lines cross or are adjacent to a wetland, water body, or grain field used by birds, or where they separate feeding and roosting areas or feeding and nesting areas, or where they separate two bodies of water. Migratory waterfowl involved in local movements along lakes and reservoirs and between water bodies and feeding sites fly at lower altitudes and therefore are more vulnerable than birds engaged in long-distance travel.

4.5.3.2 CRS Impacts

Certain features of the CRS structures would influence the potential for bird collisions. Each transmit antenna array would be a series of towers varying in height between 35 and 135 ft aligned in a row approximately 5,000 ft long, on which the antenna elements (up to 52 ft in length) and backscreen would be mounted. The backscreen would be a wire mesh ranging in size from an approximately 24 inch square pattern to a 6 inch by 12 inch rectangular pattern. Each receive antenna array would be similar except that it would be approximately 19,000 ft long and the backscreen would be only 65 ft tall.

The major design feature that would adversely affect birds is the backscreen. Bird collisions would be virtually unavoidable when environmental conditions forced birds to fly low across the sites because it would be almost impossible for a bird to pass though the small openings in the backscreen. However, the structure on which the backscreen would be mounted might help to reduce impacts because it would be more visible to birds than the backscreen wires and might cause them to fly over the array.

Weather conditions in the project region would have an effect on bird collisions with the CRS structures because they influence flight altitude. In many parts of the region, frequent, heavy fogs occur near water bodies in spring and fall. In North Dakota, fog reduces visibility to less than 1/4 mile an average of one day each month during spring and fall (Krapu, 1974). Overcast, rainy conditions occur most often in the spring and fall in the region as well. "The average wind speed [in the area] is greatest during April and May with prevailing northwesterly winds in April resulting in a substantial northward movement of waterfowl at low altitudes" (Krapu, 1974). Thus, the prevailing weather conditions in the project region indicate that collisions due to weather would be more common in spring and fall than in summer and winter.

Another pertinent environmental factor is habitat type. Generally speaking, the study areas contain many wetlands and open water habitats that birds use for feeding, roosting, and breeding. Birds fly at low altitudes in the vicinity of these habitats while taking off and landing and while flying between them. Flying at these low altitudes increases their chances of striking the proposed CRS antenna arrays.

Dense bird populations in the spring and fall in the study areas would also influence bird collisions. The large bird populations result from bird migration along the Central Flyway in spring and fall. Populations are higher in summer than in winter because of the presence of important summer breeding grounds in the prairie pothole region. However, the concentration of birds is generally not as high as in spring and fall, so the potential for bird collisions will be greatest in these seasons.

The CRS study areas have ecological characteristics that influence the potential for bird collisions. Dahlen, Goose River, Galesburg, and Wheaton SW all contain significant wetlands and ponds that serve as waterfowl habitat. Thief River Falls has extensive wetlands in the west and central sections. Blanchard, Wheaton N, and Wheaton SE contain relatively few wetlands or ponds. Placing the antenna arrays in or adjacent to prime bird habitats such as wetlands and ponds would increase the chance that birds would collide with the structures.

4.5.3.3 Mitigation

When selecting a site for the receive and transmit antenna arrays, several factors would be taken into account to minimize bird collisions. The most effective way to reduce collisions is to avoid areas of high bird concentration. Once the site has been selected, structural modifications, such as increasing the visibility of the backscreen, and environmental modifications, such as screening the arrays with a shelterbelt could also reduce impacts. However, there is little experience with extended structures such as the CRS arrays, so what measures would be most effective in preventing bird collisions with the arrays are not known.

The Air Force would consider these mitigation techniques in carrying out the proposed action. Post construction monitoring would determine the effectiveness of implemental techniques in reducing bird collisions. Based on the results of such monitoring, the mitigation measures could be modified.

4.5.3.3.1 Site Selection

Areas of high bird concentrations include wetlands, open water bodies, Waterfowl Production Areas, National Wildlife Refuges and flyways. If such areas can be avoided by several kilometers, the probability of catastrophic losses would be greatly reduced (Thompson, 1978). Faanes (1984) recommends that structures be located at least 1/4 mile from the edge of water areas that support large bird concentrations and at least 300 ft from the edge of prairie potholes. In selecting a study area, the Air Force would avoid areas with high bird concentrations, if possible.

Observations of local bird movement patterns and concentations would be used to help select a specific site within the study area. Local low-altitude feeding flights would be of particular interest. Areas of frequent and heavy fog would be avoided to reduce the probability of bird collisions due to poor visibility. Locating the antenna arrays parallel to the prevailing winds would reduce the likelihood of bird collisions. However, this is generally not practical because the alignment of the antenna arrays is dictated by radar coverage requirements.

4.5.3.3.2. Structural Modifications

After site selection, bird impacts could be further mitigated by increasing the visibility of the backscreen so that birds would be able to see it under a variety of conditions. Visibility might be enhanced by attaching highly visible objects, such as tape, streamers, or flags to the array. Yellow-green is the color most visible to birds during the day, and yellow-green luminescent markers are most effective at night. Also, flashing, dimly lit, fluorescent lights have been shown to reduce bird collisions with towers at night.

Another method of diverting birds from the CRJ arrays is to audibly or visually repel them. Wind-operated whistles or bells may be useful. Windmills or wind-animated scarecrows made to resemble hunters, canids, or raptors might be effective in repelling birds during daylight hours (Thompson, 1978).

4.5.3.3.3 Environmental Modifications

One effective environmental modification would be to screen the antenna arrays with trees, or other man-made structures. Shelter belts, high wooden fences, or other highly visible structures could force birds to fly over the backscreen even if they cannot see it. Shelterbelts would also provide new habitat for wildlife dependent on these woodlands as well as help reduce wind erosion.

Modifying habitats may also help reduce bird collisions. If siting the antenna arrays near bird habitat cannot be avoided, new bird habitat could be created away from the site to attract birds away from the site. For example, if feeding and roosting areas are separated by a site, new feeding and roosting areas of greater value that are not separated by the site might be created.

4.5.4 Study Areas

4.5.4.1 Dahlen

Wildlife habitat affected at the Dahlen study area would include stream-associated emergent wetlands and shelter belts. The number of intermittent streams would make it impossible to construct a receive antenna array without destroying emergent wetland vegetation along several miles of intermittent streams, as well as numerous shelter belts, perhaps totaling 50 to 100 acres of woodland. The action would reduce the available habitat for several species of amphibians, reptiles, birds, and mammals. Extensive grading would be required to prepare a level site, and this would cause erosion and runoff into the watercourses draining the area, with consequent problems of siltation. Runoff from the northern part of the area could increase siltation and turbidity in the reservoir on the Forest River, which would adversely affect the aquatic biota and thus the recreational fishery.

The potential for bird collisions at this study area is relatively high because the antenna arrays would have to be placed close to important bird habitats (wetlands). The wetlands attract heavy concentrations of birds, and the higher the concentration of birds, the greater the likelihood of collisions.

4.5.4.2 Goose River

Any receive antenna array in the Goose River study area would impact numerous stream-associated and pothole emergent wetlands, with consequent loss of habitat for migrating birds, reptiles, amphibians, and water-dependent mammals. Several shelter belts would be destroyed as well, diminishing cover for large mammals and habitat for several smaller mammals and birds. The impact on birds due to collisions at this study area would be similar to those at Dahlen.

4.5.4.3 Galesburg

Although Galesburg is primarily farmland, extensive wetland habitat would be eliminated by antenna arrays at this study area. The importance of the area for waterfowl is indicated by the six WPAs and three federal wetland easements in the study area. Even an array sited to avoid these protected areas would affect numerous valuable wetlands. Waterfowl and other water-dependent birds, amphibians, reptiles, and several species of mammals would be displaced or lost.

Because of the extensive wetlands in this area, the possibility of bird collisions would be similar to those described for Dahlen.

The loss of several shelter belts would reduce habitat for several species of mammals, including deer and moose, and the exclusion fence would remove potential large animal habitat, as well as impeding movement of the large mammals known to inhabit the area.

A few birds may feed on the cultivated fields in this area, but their number is limited because of the lack of available wetlands for breeding and roosting in the immediate area.

4.5.4.4 Blanchard

This study area contains minimal wildlife habitat. Receive arrays in the south-central part of the area would eliminate a few small temporary wetlands, but these are more abundant in adjacent areas, and the loss of breeding waterfowl and other habitat would be proportionately very small.

A few shelter belts, generally no more than 1,000 ft in length and planted near houses, would also be eliminated. These provide habitats for some small animals, but probably not for large mammals because of their proximity to human habitation.

The limited number of birds and mammals associated with agricultural cropland would be affected most strongly by a site in this area. A few birds may feed on the cultivated fields in this area, but their number is small because of the lack of available wetlands for breeding and roosting in the immediate area. Because so few birds live in the area, the probability of collisions with CRS structures is relatively low.

4.5.4.5 Thief River Falls

Any installation in the south central or eastern parts of this study area would eliminate good habitat for large mammals, as well as for several species of small mammals and birds. A significant number of deer and moose are known to be in the area, and they would be excluded from some of their former habitat. Their movements between feeding grounds, or between feeding grounds and cover would be affected by the very long, fenced antenna arrays. Wetland habitat eliminated would reduce the number of waterfowl and other birds, amphibians, reptiles, and mammals.

Because of the extensive bird habitats in the south-central and eastern sections of this study area, impacts on birds from collision would be substantial. Birds in this area make many low-altitude flights between feeding and roosting areas that would increase their risk of collision.

In the northwestern part of the area, a small amount of woodland, probably no more than 10 acres, might be removed for the antenna arrays. Permanent wetlands and their associated wildlife habitat could probably be avoided entirely.

4.5.4.6 Wheaton N

Draining of temporary wetlands at this study area would result in some loss of migratory bird habitat.

Bird collisions would be minimal because the area has a small amount of bird habitat. Deer movements would be impeded, but the deer populations are probably low because the area has very small amounts of woodland for cover.

4.5.4.7 Wheaton SE

The principal wildlife areas affected at this study area would be wetlands associated with Twelvemile Creek and its tributaries. Wetland-dependent birds and mammals in these areas would be forced to relocate. Waterfowl would be prevented from using temporary wetlands, and deer would be excluded from a former marginal habitat.

4.5.4.8 Wheaton SW

A substantial amount of breeding and rooting habitat provided by temporary ponds and their associated emergent wetlands would be eliminated by draining and filling of temporary wetlands at this study area.

It would be difficult to avoid locations with high concentrations of birds in this area, and therefore the risk of bird collisions would be high.

Some ditches and temporary streams and associated wetlands that provide habitat for small birds and mammals would have to be moved. Because of the relief of the land at this area, site grading may cause some erosion into ditches and their associated wetlands, which would diminish the value of this habitat.

4.5.4.9 Amherst

Antenna sites located in the extreme northern or the southern parts of this area would eliminate wetland habitat for water-associated wildlife, possibly including an area of especially high waterfowl use on the western side of the area. Impacts due to bird collisions in the central portions of the study area would be small because of the limited amount of bird habitat. In the north-central part of the area, it might be possible to avoid most wetlands, but the wildlife habitat associated with several large shelter belts would be lost. Deer would be driven from their former habitat, and their movements would be altered.

4.6. Air Quality

Sources of air quality impacts from the CRS would be related to vehicles and the standby power plants. During construction, pollutants would be emitted from internal combustion engines in construction equipment, and dust (suspended particulates) would result from earthmoving and increased traffic.

Commercial power would be used during operation. Each site would also have a 1-MW, Class B standby diesel generator system. This system would be briefly tested every two weeks and operate less than 100 hours per year. The infrequent use of these generators would cause only minor emissions and would not affect local or regional air quality.

Both construction workers and operations personnel would commute to the sites from their residences, which would likely be nearby. The additional traffic volume and the resultant pollutant emissions would be a small increase over the existing traffic and its emissions.

Fuel storage is another potential source of air pollutants. The Air Force would use proper fuel storage techniques and comply with all applicable federal, state, and local regulations.

In general, the areas in which the CRS transmit and receive sites may be built have few sources of emissions, and the local air quality meets all ambient standards. No measurable effects on local air quality would result from either construction or operation of the CRS. Nevertheless, the Air Force would comply with all applicable laws and regulations.

In all three states, windblown dust can occasionally be a problem. For example, South Dakota has a 100-mi^2 nonattainment area for total suspended particulates (TSP); it is located along the eastern edge of the Black Hills and includes the Rapid City metropolitan area. The Amherst study area, however, is not near this nonattainment area and would generally have TSP levels more closely resembling those for Big Stone City, South Dakota. TSP monitoring there showed an annual geometric mean of 27.3 $\mu g/m^3$, and no sample exceeded the 24-hour primary or secondary standards.

Dust is a less severe problem than in North or South Dakota, but it can be occasionally a temporary, local irritants in western Minnesota. Big Stone City is approximately 20 miles south of the Wheaton SW study area, and the measured concentrations there are generally representative of the degree to which the Wheaton study areas meet the TSP standards.

Because of the potential for substantial dust generation, the Air Force would direct that, during construction, common wetting procedures be used by the contractors.

4.7 Population

The operations center proposed for Grand Forks AFB would have the largest personnel contingent of the CRS sites. Like existing Base operations, the center is likely to have its greatest influence on Grand Forks County, North Dakota, and Polk County, Minnesota. During full operation, the maximum projected increase in personnel at the base is 390; considering dependents, the change would be less than 1% of the combined population of Grand Forks and Polk counties--an insignificant increase.

Employment at the transmit and receive sites would total 50 civilian personnel at each site. This number could be easily accommodated in any study area; at maximum, the CRS would cause less than a 1% increase in the population of any study area which would be an insignificant change.

4.8 Economy

The following discussion deals with expected economic impacts primarily at township and county scales. However, the CRS transmit and

receive sites would be constructed on land purchased or leased from a relatively small number of current owners. The Air Force recognizes that this group of people would experience greater impacts than the average person living near the sites.

4.8.1 Employment

4.8.1.1 Overview

Construction employment is expected to average about 100-125 over the construction period. It would peak at about 250 during the second year. The systems contractor, which has not yet been selected, would be responsible for hiring. Because nearby residents have many of the skills required, much of the economic benefit to the area would begin at the start of construction and last throughout the operation phase. Some employees in skilled trades, however, are likely to be imported from outside the immediate areas.

During operation, after about a year of testing, the CRS is expected to employ about 490 people. Of these, approximately 290 are expected to be military personnel stationed at Grand Forks AFB, and 200 are expected to be civilian, half of whom would work at the transmit and receive sites.

4.8.1.2 Operations Center

During the operating phase, projected employment at the operations center would add 390 people to the labor force, less than 1% of the total if all new employees are from outside of the area, and significantly less than 1% if some of the employees are hired locally or are serving existing functions at the base. The combined effect of direct and induced employment (i.e., the multiplier effect) is expected to be a reduction of approximately 0.09% in the overall unemployment rate.

4.8.1.3 Transmit and Receive Sites

The largest employment impact at the transmit and receive sites would be during construction. The nature and sources of the work force are uncertain because a contractor has not been selected. Individual contractors determine hiring practices and the proportion of workers imported to an area for a particular project. Because a number of contractors operate in and around the area, a large percentage of the workers would probably be hired from the region. It is also likely that many of the workers would come from some distance around the construction sites. Therefore, direct local employment is unlikely to significantly affect any particular community. However, because each site would have an average of 100 workers during the construction period, indirect local economic effects and employment are likely to be apparent.

During system operation, employment of an additional 50 people would have only marginal consequences on the total labor force and unemployment rates in the larger regions surrounding Grand Forks, Fargo, Thief River Falls, and Aberdeen. In Traverse County, the region with the smallest labor force, 50 additional workers would increase the labor force of 2,200 people by 2.3% if all workers were hired from outside the region. If all workers were hired locally, the unemployment rate would drop by 2.3 percentage points. Indirect economic effects of increased spending might double this benefit.

4.8.2 Income

The major income effects for a particular community during site preparation and construction would depend on the resident location of the contractors performing the site work. Because no contractors have yet been selected estimates of local income effects are difficult to make.

Expenditures during construction at each transmit and receive site are expected to total $15-20 million. A typical breakdown of these expenditures, based on the Census of Construction Industries (U.S. Department of Commerce, 1982), shows that payrolls and fringe benefits would account for about 30-40% of the total contract, materials would account for another 30-40%, and the remainder would be made up of other miscellaneous expenditures. Subcontracting generally is 20-25% of the total contract award.

Total expenditures in a local area would depend largely on the communities' ability to supply labor and materials during the construction phase. This study assumed that in a smaller community, such as Traverse County, perhaps half of the typical subcontracting level might be obtained by area firms--an amount equal to $1.5-2.0 million. In addition, $1-2 million might be spent on materials, supplies, and fuel. In total, expenditures locally might equal $2.5-4.0 million over the entire construction phase. This would amount to an increase of 1-3% in area income, including indirect effects.

In larger communities, such as the area around Brown County, South Dakota, a larger share of total expenditures is likely to be retained locally. If all contracting were to be performed and supplied by area firms, total regional incomes would rise by as much as 3% over the entire construction period, including indirect income effects.

Construction expenditures at the operations center site are expected to total about $10 million over the construction period. In the Grand Forks area, this would amount to approximately 0.5% of regional income. Including indirect effects, area income might rise by as much as 1% during the construction phase.

During CRS operation, the addition of 50 workers compensated at the average pay rate for civilian employees at Grand Forks AFB will increase total income in one of the larger communities by a negligible amount. Effects in smaller communities would be greater. For example, in Traverse County, local income would be directly increased by as much as 1.5% and indirect benefits could perhaps double this amount.

An adverse impact would result from the reduction of farmed land. Annual farm incomes ranged between about $75 and $144 per acre in 1982. Although incomes have declined in many areas since that time, these figures are a reasonable approximation of gross income per acre. If 50% of this total is retained by the local community as proprietor and labor income and net proceeds from the sale of other, mostly farm related goods and services, the net loss to the various communities would range between $38 and $72 per acre of land no longer farmed. If all land acquired for a site were productive (as opposed to idle or non-income generating), total annual income loss would range between $76,000 and $216,000 per site.

Thus, the local income gain from the CRS near the transmit and receive sites would be between 2.5 and 8 times the income loss resulting from the reduction in farming. The gained income would be earned by different people and spent for a different mix of good and services, primarily non-farm.

4.8.3 Fiscal Conditions

To the extent that land is purchased rather than leased, the major fiscal impacts would result from removal of land and buildings from the tax base. Approximately 2,400 acres would be required for each site. For any county in the project region, these amounts would cause the loss of less than 1% of its taxes if the land removed were of average value.

For a particular township or school district, however, losses would be more significant. The exact impact would be determined by the percentage of taxable land that is removed by the site. If an entire site were to be contained within a given township, the tax loss--assuming average land values--would be as much as 18.5% of the township's tax base. Depending on the ownership and use of this land, the tax consequences discussed above may be of less impact than indicated.

4.8.4 Agricultural Impacts

The principal agricultural impact would be the reduction in farm incomes discussed above. In any of the counties in the project region, the land required for transmit or receive sites amounts to less than 1% of the currently farmed acreage. For the region as a whole, such a reduction is negligible.

According to Census of Agriculture statistics, farm acreage in production has declined significantly over the past few years. Between 1978 and 1982 all areas examined in this study with the exception of the Minnesota-S region lost significantly more farm land than proposed to be removed by this system.

4.9 Housing

In part because of recent decreases in population and the number of households experienced by many of the study areas, all of the areas examined have more than adequate vacant housing units to accommodate any projected influx of workers. Vacant, unoccupied, year-round housing for every area currently exceeds expected peak construction employment. Combined with available mobile home sites and temporary lodging space, all regions have a more than adequate supply of housing.

4.10 Community Facilities and Services

4.10.1 Educational System

All study areas have access to a full range of educational facilities, from preschool to postsecondary education. These facilities are adequate for, and would not be burdened by, any anticipated needs related to the proposed action.

4.10.2 Health Care

Medical facilities and practitioners are supplied through a number of private practices, regional hospitals, and clinics. All of the urbanized areas in the project region, as well as Grand Forks AFB itself, have medical facilities that offer a range of standard care. In the larger communities of Grand Forks and Fargo, specialists are also available. These resources are adequate for any needs created by the CRS.

4.10.3 Transportation

4.10.3.1 Overview

During construction, workers would commute to the job site, materials would be delivered to the job site, and equipment would be operating within the confines of the site. Workers commuting to the site would travel in automobiles, pick-up trucks, or vans. Materials would be delivered in tractor-trailers, flat-bed trailers, and ready-mix concrete trucks. Construction equipment would primarily be engaged in earth moving and would consist of dump trucks, bulldozers, and other off-road equipment. In addition, cranes would be used to erect the steel antenna support towers.

During operation, added vehicles would be primarily passenger automobiles, pick-up trucks, or vans used for commuting to the site.

4.10.3.2 Transmit and Receive Sites

The most significant potential impact would be the interruption of some county roads. Specific impacts cannot be determined without more detailed informatin on site selection and sector layout, but the interruption of the unpaved roads is not expected to create more than a 2-mile detour from existing roads.

Construction vehicles would use state roads and better-quality county roads to reach the CRS sites. These roads should be able to support construction and operation traffic without improvements. However, the construction contractor would be required to maintain these roads as necessary during construction.

Light-duty roads might require gravel surfacing prior to site construction and contractor maintenance during site construction. The Air Force does not plan to pave existing gravel roads, but would improve the existing gravel surfaces as required. Which roads require improvement would depend on the location of the site and of the selected construction routes.

Two of the study areas, Galesburg and eastern Thief River Falls, often have large areas of standing water in spring. Any new roads constructed there would require additional fill material to raise the road bed and possibly additional drainage structures. Additional fill to raise existing roads might also be required to improve wet-weather access.

Access to sites within the four Minnesota study areas (Thief River Falls, Wheaton N, Wheaton SE, and Wheaton SW) by means of state and county roads would be constrained by load restrictions. Either construction loads would have to be limited to the restricted values, or the roads would have to be improved with asphalt or gravel materials to raise their load capacity.

4.10.3.3 Grand Forks AFB

The preferred construction access to the operations center would be through the South Gate. The base road system could handle the traffic generated by both the construction and the operation of the operations center. Off-base traffic generated during construction and operation would not affect the road system leading to the base.

4.10.4 Solid Waste

4.10.4.1 Transmit and Receive Sites

Solid waste generated during construction would be primarily construction scrap and domestic waste such as packaging from foods and supplies during operation. The contractor would be required to dispose of the waste in an acceptable manner.

During construction, the contractor could hire a disposal company or haul the material to the nearest available landfill. During operation, the Air Force could also hire a disposal company.

4.10.4.5 Grand Forks AFB

Solid waste generated during both construction and operation would consist of domestic waste from construction personnel, such as food wrappers, and construction material waste, such as dry-wall and wood scraps. The construction contractor would either haul the material away or hire a local disposal company to transport the solid waste to the Grand Forks city landfill.

Solid waste generated during operation would also consist primarily of domestic waste. This material would add to the overall waste disposal requirements of the Grand Forks AFB.

4.11 Aesthetics

Aesthetic impacts are visual changes resulting from construction or operation of the CRS that would significantly contrast with existing landscape features. Scenic quality and viewer sensitivity are the key factors in such an assessment.

Scenic quality refers to the physical features of a landscape scene, including both its natural features (such as landform, vegetation, water, and soils) and the human modifications that have been made to the landscape (such as roads, buildings, and utility lines). These features make up the distinguishable line, form, color, and texture of the landscape composition; these in turn determine its scenic quality on the basis of criteria such as distinctiveness, variety, harmony, balance, and uniqueness. Scenic quality is perhaps best described as the overall impression an observer retains after driving through, walking through, or flying over an area.

Sensitivity represents the value of the landscape scene to the viewing public. It takes into account the types of viewers exposed to the landscape scene; when and from where they would view the landscape; the angle and distance of the view; the frequency of view; and the range of expectations or preconceptions that viewers may have about what is being viewed.

Clearing, leveling, and fencing 2,400+ acres of land and constructing antenna arrays, groundscreens, access roads, and other support facilities would result in noticeable modifications to landscape color, texture, and line for most sites within the study areas. The 35- to 135-ft tall transmit arrays and the 65-ft tall receive arrays, ranging from 5,000 to 9,000 ft long, would introduce a dominant vertical element in local landscapes when viewed from within 3 miles. At a distance of 3 miles or more, the antenna support towers and backscreen become difficult to distinguish clearly at most angles of view.

Temporary aesthetic impacts associated with construction activities (dust, noise, debris piles) and the presence of heavy equipment would also occur. These impacts are not significant.

Overall, landscape modifications resulting from the proposed project would not contrast significantly with existing landscape features. Appendix E summarizes the assessment of scenic impacts for each of the nine study areas.

4.12 Cultural Resources

4.12.1 Overview

No systematic inventory of cultural resources has been conducted over large blocks of land in any of the nine study areas. Five study areas contain no recorded prehistoric or historic sites. The other four contain only a few. Just six prehistoric sites and three historic sites are recorded within the approximately 800 mi^2 that make up the nine study areas, and no sites, either recorded or unrecorded, are listed in the National Register of Historic Places. Given the lack of previous inventories and the scarcity of recorded sites, it is impossible to predict the precise locations of sites that might be discovered.

Systematic efforts to inventory prehistoric and historic cultural sites in the study region, however, have identified several landforms with higher than average site density. Many sites have been recorded along the Red River of the North, the James River, and their tributaries. The Red River-Bois de Sioux River-Lake Traverse-Big Stone Lake-Minnesota River waterway links Lake Winnipeg and Hudson Bay with the Mississippi River and the Gulf of Mexico. This travel route was undoubtedly important in prehistory and was certainly important historically. Many kinds of settlements, both temporary and permanent, have been established along this route. The beaches of former glacial Lake Agassiz were also favored locations for prehistoric settlement, especially where the beaches were cut by streams entering the Red River Valley. There are hints that former glacial Lake Dakota beach areas were also important at times during prehistory. The Red River Trails were established during the growth era of the fur trade. They were extremely important and heavily used travel routes that linked the settlements in Manitoba to those in southern Minnesota. In light of these patterns of past land use, all nine study areas are likely to contain one or more localities with high densities of cultural sites.

4.12.2 Study Areas

4.12.2.1 Dahlen

Results from portions of two survey projects conducted within the study area revealed no cultural resource properties. However, one historic site lead is on record at the SHSND, several possible historic sites and structures in the study area could be of significance.

Intensive and extensive cultural resource inventories have been conducted in the townships adjacent to the eastern study area boundary focusing on locations along the Forest and Turtle rivers (Cole 1968a, 1968c; Larson et al., 1986; Loendorf, 1977; Loendorf and Good, 1974; Woolworth Research Associates, 1978). More than 50 prehistoric sites, most of them burial mounds, are recorded within 6 miles of the study area. Both the Middle and South branches of the Forest River traverse the study area, and the unsurveyed locations along these streams have great potential to have been as intensively used by prehistoric groups as the area immediately to the east.

A portion of what is probably the Ridge Trail was recorded 4 miles east of the study area (Larson et al., 1986). Travel routes and archeological evidence of the Metis and earliest Euro-Americans in the area have particularly sensitive research potential.

4.12.2.2 Goose River

No cultural resource inventories have been conducted within the Goose River study area; however, the area has three possible sites of historical significance.

The Goose River and its tributaries, the Little Goose River and Beaver Creek, flow through the study area on a southeasterly course to the Red River. These waterways provide some of the natural resources that would attract human habitation. Farther north on the Forest and Turtle rivers, and southeast on the Goose River, prehistoric sites appear to be clustered near the streams. These factors may indicate that the prospects for locating prehistoric sites within the study area are good. Very few surveys have been conducted in areas away from the flowing streams, and therefore little archeological informatin about these areas is available. However, elsewhere in the Northeastern Plains, high site densities are known to exist around prairie pothole lakes and sloughs such as those in the western study area (Fox, 1980; Lensink, 1979).

The western branch of the Ridge Trail stayed close to the west side of the Goose River, crossing the northeastern segment of the study area. It is probable that remnants of this early travel route are still visible; they would constitute an important historical cultural resource.

4.12.2.3 Galesburg

No cultural resource surveys have been performed within Galesburg. However, one prehistoric site lead is on record, and evidence suggests that an old railroad grade should be recorded as historic site. A historic trail also parallels the eastern study area perimeter.

The South Branch Goose River flows through the northwestern part of the study area. Sites on the Goose River farther northeast are known, and others are probably present on this tributary as well. The study area is situated on sediments deposited by streams flowing into the

receding glacial Lake Agassiz. Had the area been occupied in early prehistoric periods, sites may be buried beneath the surface. Little is known about the area because so little cultural resource work has been conducted. Prehistoric human burial mound sites and cultural material scatters occur north of the study area on the Goose River and south and east on the Maple River. The potential for prehistoric sites within the study area is high.

4.12.2.4 Blanchard

No cultural resource inventories have been conducted within Blanchard; however, two leads that may be of historical significance are recorded, and a historic trail may still be visible.

The pattern of prehistoric settlement around permanent rivers has been documented just to the north of the North Dakota-N region and along the Goose River just outside Blanchard. The Elm River, which bisects the study area, would probably have attracted similar prehistoric occupation from the time that glacial Lake Agassiz drained late in the Paleo-Indian period.

No sites are recorded, primarily because no cultural inventories have been conducted. Site leads for cultural material scatters are on file for two locations within a mile of the northern border of the study area. One recorded site, 32TR101, is located on the Goose River 3 miles northeast of the study area. Evidence of prehistoric use of the Elm River and its tributaries in the study area is likely to be found. The remains of early Euro-American exploitation of the area may be present also. Remnants of the trail should be evident in areas that have not been cultivated.

4.12.2.5 Thief River Falls

No systematic cultural resource surveys have been conducted in Thief River Falls. However, one prehistoric site, one prehistoric find spot, and one historic site have been recorded.

Although no surveys have been conducted in the study area, some nearby areas have been examined. Only a very small portion of the two-county area has been surveyed. Archeological deposits are typically found in soils overlying glacial lake sediments. On the basis of findings elsewhere on the Agassiz plain, these soils are expected to be less than 1.5 meters thick in the study area. (cf. Artz, 1984 and Michlovic, 1984).

Prehistoric sites recorded in Polk and Pennington counties include Woodland habitation and burial occupations, Old Copper Archaic occupations, and several lithic scatters. These sites have been located near Fertile, Red Lake River, Maple Lake, Sand Hill River, Cameron Lake, Oak Lake, and East Grand Forks.

Arvilla mounds near the study area include the Warner and Lee Mounds near Fertile. They are situated on the Sand Hill River delta region on the eastern perimeter of former glacial Lake Agassiz. Haarstad (21MA6) is 3 miles east of Middle River and backed against the Campbell beach ridge in Marshall County. Snake River mounds are east of Snake River and some 29 miles east of the Red River near Warren in Marshall County. Several mounds are located on the Campbell Beach on the Red Lake River (Johnson, 1973).

The paucity of recorded sites in the study area is the result of a lack of survey coverage rather than a lack of cultural resources. In examining the cultural sequences represented in these and neighboring counties, it is apparent that certain cultural resources should also be expected in the study area. Materials spanning the late Paleo-Indian period to historic times have been documented in the Red River Valley (Johnson, 1962, 1964a, 1973; Michlovic, 1983; Schneider, 1982b). The study area also probably contains evidence for similar cultural developments. Evidence from surrounding areas indicates that mounds are frequently located on the surface of the Campbell beach and on the Sand Hill River delta region of glacial Lake Agassiz (Johnson, 1973). In addition, several copper artifacts have been found in Polk and Pennington counties on the Campbell beach and inside Ojata beach (Johnson, 1964a). Cultural traditions likely to be represented in the study area include Paleo-Indian, Plains Archaic (Old Copper), Middle Woodland (Laurel, Brainerd), Late Middle Woodland (Arvilla), and Late Woodland (Kathio, Clam River, Blackduck, Ogechie, and Sandy Lake). Also, the presence of the Woods Trail in the study area suggests a high likelihood of early historic sites such as Metis camps, bison kills, and homesteads.

4.12.2.6 Wheaton N

Although no cultural resource surveys have been conducted in Wheaton N, and no sites have been recorded, both prehistoric and historic cultural resources are likely to be present. One prehistoric site was located a mile east of the study area. Also, lithic scatters were located to the south and southeast on or near drainages (Lane, 1974). Historic sites are likely in this area, given its close proximity to Tintah City which does have recorded historic buildings. Homesteads are also likely to be present.

4.12.2.7 Wheaton SE

Wheaton SE has not been surveyed for cultural resource properties; however, one historic site is on record.

No prehistoric sites have been recorded for this study area; however, given the presence of natural drainages, sites are probably present. This probability is supported by results from the Dome survey which located sites just east of the area (Lane, 1974). The Red River

was heavily populated prehistorically, and these adjoining areas are also likely to have been inhabited or used, although probably less intensively than the immediate Red River vicinity. Additional historic sites are also probable because an old school is present in this area. Homesteads are to be expected.

4.12.2.8 Wheaton SW

The site files for the Wheaton SW study area record four prehistoric sites and two historic sites. Two trails that are of major historic significance also border portions of the study area.

The Lake Traverse area has been used extensively by prehistoric and historic peoples. Evidence has been found for Paleo-Indian to historic occupations. There is a very high probability of additional prehistoric and historic sites being present in the Wheaton Southwest study area.

4.12.2.9 Amherst

Although no cultural resource surveys are known to have been conducted, one prehistoric site is recorded in Amherst. Most of the previous cultural resources work of major proportions has been conducted along the James River 15 miles to the west of the study areas, and on the Prairie Coteau 15 miles to the east. Work in Day County has concentrated on the Waubay Wildlife Refuge atop the Prairie Coteau (Keller and Zimmerman, 1981). The density of prehistoric sites atop the Prairie Coteau is high (Rood and Rood, 1984). Large parts of the James River valley in Brown County have been surveyed by the State Archaeological Research Center (Keller and Keller, 1983). A northwest to southeast corridor through Brown County was surveyed for the Northern Border Pipeline (Hannus, 1982). Previous projects in these surrounding areas have produced evidence for the presence of prehistoric people since late in the Paleo-Indian period.

In Marshall, Day, and Brown counties, many earthen mound features have been a focus of study since Euro-Americans have taken over the territory (Lewis, undated; Sigstad and Sigstad, 1973). These mounds usually mark the locations of prehistoric Indian graves.

Historic Fort Sisseton (originally Fort Wadsworth) is a National Register site on the Prairie Coteau in Marshall County. It is one of several truly prominent cultural sites in the three-county area. Other prominent sites are prehistoric fortified earthlodge villages atop the Coteau and protohistoric Dakota trade fair sites along the James River.

This study area is part of the Upper James study region defined for South Dakota's draft archeological resource management plan (Buechler, 1984). Some of the research questions and goals that have been identified in the management plan are pertinent. Several Paleo-Indian sites have been found in surrounding areas; the plan suggests that an examination of glacial Lake Dakota shorelines might locate others. One or more

glacial lake shorelines transect the study area. The plan suggests that sites of the Plains Woodland periods are shallowly buried in lake plain sediments. Such sites would be expected to be buried shallowly in much of the study area. The plan identifies a need for basic cultural site inventory research in areas outside the James River Valley.

4.12.3 Mitigation

No systematic cultural resources inventories have been conducted on any large blocks of land in any of the nine study areas. Given the lack of previous inventories and the scarcity of recorded sites, it is impossible to predict site locations. When a tract is selected for construction of the CRS sites, reconnaissance surveys would be conducted to identify cultural resources that might be affected. If any cultural resources were found, appropriate mitigation measures consistent with federal and state laws and regulations would be taken.

4.13 Electromagnetic Interference and Hazard Effects

4.13.1 Radiofrequency Radiation

The direct impacts of the CRS on the environment depend primarily on the magnitude, nature, and distribution of the RFR. A detailed description of the OTH-B radar is given in Appendix A, and a comprehensive technical description of its RFR is presented in Appendix B. Calculated values reported in this section are based on the field model described in Appendix B. Comparison of the measured and calculated values at the ERS at Moscow, Maine, shows that the field model is well founded and conservative (see Table B-5).

This section describes the power densities of the RFR that would exist in the vicinity of the CRS transmit site. Even though the ground in the project region is quite conductive, the average power densities at ground level in front of the antenna arrays would decrease rather rapidly with distance. To avoid possible harm, an exclusion fence would be constructed to prevent humans and animals from approaching too close to the antennas. In all cases, the highest values of average power density to which the general public would be exposed just outside the exclusion fence would be the maximum permissible values adopted by ANSI (ANSI, 1982).

4.13.1.1 RFR Fields

Time-averaged values of RFR are based on continuous radiation from all four transmit arrays and include a factor of 0.14 to account for the fact that the beam would be pointed in any one direction only part of the time.* However, some specific potential effects related to

*The beam points in a particular direction only 0.125 of the time. The larger factor (0.140) results from spillover of power from adjacent beams.

electromagnetic interference depend on maximum values of power density and the detailed manner in which the frequency varies with time. For this reason, maximum values of power density and electric field intensity are also given. Appendix A includes details of representative modulation patterns.

A quantitative discussion of the intensity and possible effects of RFR requires use of a set of consistent units. Following common usage, all values of radiation intensity are expressed as power density in milliwatts per square centimeter (mW/cm^2); the unit used for area is square centimeters. Because land surveying is still based on English units, distances and dimensions are expressed in feet. Electric field intensities are given in volts per meter (V/m), the accepted units for this parameter. The symbol Z is used to identify the angle in degrees between the direction to a particular point and a line perpendicular to the applicable antenna array.

4.13.1.2 Identification of Sectors

Figure 4-1 shows the space subdivisions used for calculating RFR values in the vicinity of an OTH-B transmit array. The total RFR at any particular location is obtained by adding the separate contributions of all arrays at the transmit site. Actually, the electromagnetic radiation (EMR) from the four CRS arrays would not significantly overlap and the total at any particular location would be essentially the same as the amount due to the major contributor. Values of average and maximum RFR were calculated for various locations in the three sectors shown in Figure 4-1. The results of these calculations are presented in Appendix B as Figures B-5 through B-10.

The highest values of RFR are found in sector A, which is identified with the main beam of whichever antenna array is transmitting. The radiation patterns of OTH-B antennas are complicated, and different relationships are needed to describe the behavior in different regions. One important distinction is between the near field in which the power density is nearly independent of distance, and the far field, in which power density falls off sharply with increasing distance. For RFR at ground level, the most important parameter is the transition distance between these two fields, designated R_3 in Appendix B, at which the power density variation with distance changes from a $1/R^2$ behavior to one of $1/R^4$, where R is the distance from the array. Values of R_3 vary from 1,070 to 5,110. The exclusion fence would be built so that outside the fence, the ground level RFR would be below the value recommended as safe by ANSI. To further simplify the procedure, RFR values were assumed to be independent of azimuth in sector A, which extends over a total azimuth range of 240° for the complete CRS system. This assumption overstates the expected values near the scan limits.

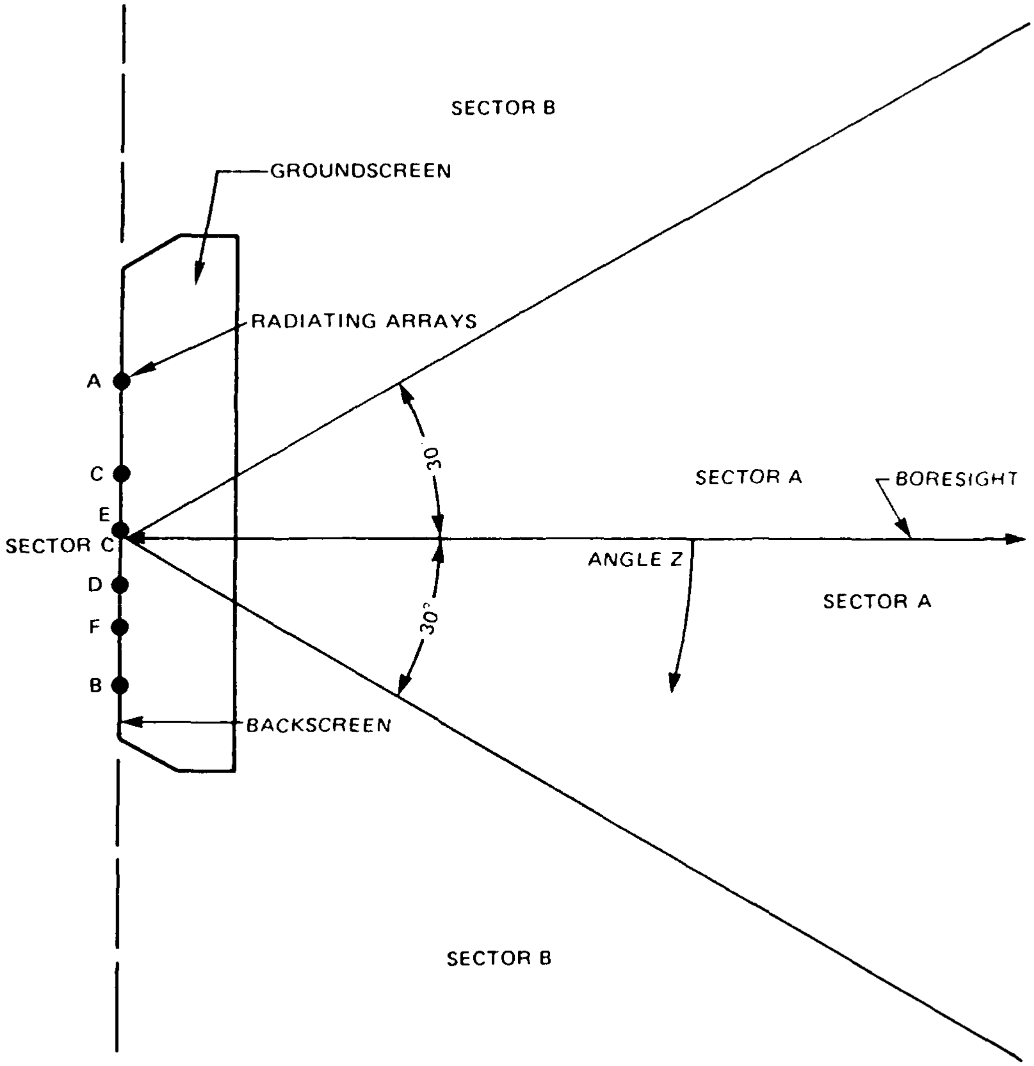


FIGURE 4-1 SPACE SUBDIVISIONS USED FOR CALCULATION OF RFR (BAND E USED FOR EXAMPLE)

Sector B extends 60° beyond the scan limits; the only RFR in this sector is caused by sidelobes, which are at least 20 times weaker than the main beam. Moreover, in the complete system of four arrays, the scanning process is such that the stronger sidelobes extend beyond the scan limits only a small fraction of the time; this reduces the effective width of sector B to about 20°.

Sector C extends 180° directly behind the backscreen of each array. Values of RFR in this sector are at least 100 times lower than corresponding values in sector A. This permits a 10 to 1 reduction of the distance to the exclusion fence.

4.13.1.3 Power Densities at the Exclusion Fence

The exclusion fence is intended to prevent people and large animals from inadvertently approaching closer than about 4,000 ft from the antenna faces. Depending on details of the transmit site selected, it would generally be necessary to separate the antennas and to fence each array separately. However, the configuration and location of the exclusion fence would be chosen so that the power density outside the fence would be below the ANSI standard.

Just outside an exclusion fence 4,000 ft from an OTH-B array, the power density would not exceed 0.02 mW/cm^2. This is the highest level of RFR to which the general public would be exposed. This ground-level estimate neglects any attenuation that might result from trees or underbrush. For comparison, the most recent average values recommended by ANSI for nonoccupational, occupational, or chronic exposure to RFR in this frequency range vary from 1.15 to 36 mW/cm^2 for a frequency range of 28 to 5 MHz. The expected values are thus well below those permitted by the ANSI standard.

4.13.2 Electromagnetic Environment

4.13.2.1 The Addition to the Environment near the Transmit Site

Operation of the CRS would change the electromagnetic environment over the frequency bands of its operation (and their harmonic frequencies) within the physical space its energy reaches. (This section on the electromagnetic environment is drawn from Appendix C, which contains a detailed analysis of the change.) This change can be described as an addition of electromagnetic energy to the electromagnetic environment, and assessed in terms of how the change may affect other systems and thus become perceptible to those using the systems. In this section, the addition to the environment is described; possible effects on systems are described in the following section.

Civilian use of the radio spectrum is under the control of the Federal Communications Commission (FCC); government use is under the control of the National Telecommunications and Information Administration (NTIA), formerly the Office of Telecommunications Policy (OTP). Because the OTH-B radar is a military system, a detailed application for spectrum support has been made through Air Force channels to the Interdepartment Radio Advisory Committee (IRAC) of the NTIA, which must authorize operation of the radar.

The OTH-B radar transmits in portions of the band from 5 to 28 MHz, which is within what is commonly called the high frequency (HF) band. An important characteristic of radio signals in this frequency band is that they can be reflected by layers of naturally occurring ionization at heights of a 100 miles or more, so that the signal is reflected back to the ground at distances of thousands of miles. This is referred to as sky-wave propagation. The band as a whole is shared with various experimental radars, radio systems for air-to-ground and ship-to-shore communications, systems for standard time and frequency broadcasts, with the Amateur Radio Service, Citizens Band radio, and others.

The specific portions of the HF band within which the OTH-B radar will transmit are those bands also occupied by transmitters of the Fixed Service and the Broadcast Service. The users of the Fixed Service operate fixed (i.e., not mobile), point-to-point links for the transmission of data or information of one sort or another from one part of the globe to another. Before the advent of communications satellites, the U.S. Armed Forces were major users of parts of the Fixed bands--operating large transmitting and receiving systems in Hawaii, California, and other locations worldwide. The Broadcast Service transmitters are also located throughout the world, broadcasting news, music, religious programs, and propaganda. They use the HF bands because the sky wave allows them to propagate their programming to areas at great distances from the transmitter, reaching audiences that they could not otherwise reach. Among these trasmitters are those of Radio Moscow, Voice of America, and the British Broadcasting Corporation (BBC); there are many others. The listeners are also, of course, spread throughout the world.

The OTH-B radar can operate on a large number of channels of various widths in the frequency range between 5 and 28 MHz, and it may or may not change frequency each time it switches its beam to illuminate a different portion of the surveillance region. Ionospheric conditions, which change with solar activity, time of day, and season of the year, dictate the particular range of frequencies that must be used to propagate the sky-wave signal to these regions. The radar operators monitor those frequencies to determine which appear to be unoccupied by other transmitters, and they then operate the radar on channels that appear to be unoccupied. From time to time, ionospheric conditions or operational considerations will require a frequency change; in the selection of the next operating frequency, the operators would place first priority on finding an acceptable channel in the Fixed bands before considering using a channel in the Broadcast bands. OTH-B radar

operating procedures, which include detailed plans for interference avoidance, are being developed. Experience with the prototype ERS indicates that the OTH-B radar can be operated without interference to other authorized users of the HF radio spectrum.

Although the function of the OTH-B radar is to propagate a sky-wave signal, some of the energy will remain near the ground and propagate by what is termed ground wave. (This is the normal daytime propagation mode for standard AM broadcast radio.) The ground-wave signal is attenuated relatively rapidly as it propagates away from the radar, and can be expected to fall to levels below the ambient radio noise at distances of 100 or 200 miles.

Not all of the radar's power enters the mainbeam. Much smaller concentrations of power appear in the antenna's sidelobes and backlobes. The maximum power density in the sidelobes is no greater than 1/20, and that in the backlobes is no greater than 1/100, of the maximum power density of the main beam. Signals propagate from these minor lobes at a much lower power level than from the main beam.

The radar will emit signals on frequencies other than the intended one, but at a much lower power level. Great care is taken in the design of the radar system to minimize such signals because they are both a waste of transmitter power and a potential source of interference with other systems. Some of these unintended frequencies are integer multiples of the intended, or fundamental, frequency and are termed harmonics. Others are less clearly related to the fundamental, and are called spurious emissions. Harmonics and spurious signals will not generally be HF signals, and thus will not generally propagate by sky wave. Furthermore, their ground waves will be rapidly attenuated.

When a radar or other transmitter radiates a modulated signal in its desired frequency band, it also transmits some energy in the directly adjacent portions of the spectrum (out-of-band energy). That transmission is close enough in frequency to propagate along with the desired signal and to create the possibility of adjacent-channel interference. (The strong possibility of adjacent-channel interference is the reason why adjacent television channels, such as 9 and 10, are not used in the same community.) The modulation of the OTH-B radar transmitters has been carefully designed to minimize the out-of-band energy; the transmitted signal has good spectral purity.

4.13.2.2 The Effects of the OTH-B Radar on Systems

The OTH-B radar's contribution to the electromagnetic environment could affect systems that use the same environment, as well as systems that are not intended to receive electromagnetic energy. Other users of the spectrum include TV, radio, and other radars. Systems or processes not intended to receive electromagnetic energy include cardiac pacemakers, electroexplosive devices (EEDs), and fuel handling. Calculations and predictions of interference summarized below are presented in Appendix C.

4.13.2.2.1 Effects on Telecommunication, Radionavigation, and Radiolocation Systems

4.13.2.2.1.1 Services That Share the Bands with the OTH-B Radar

Because the OTH-B radar will operate on frequencies that are also allocated to other services, mutual interference between the radar and the Fixed stations or interference with the listening activities of the international-broadcast audience is possible. It is to the advantage of the radar to avoid operating on frequencies that are already occupied because in such instances, the radar could suffer interference as well as producing it. Policy will thus stipulate operation in the Fixed bands whenever possible, in preference to the Broadcast bands. The Fixed bands are thought to be sufficiently uncrowded that the radar will be almost always able to find unoccupied channels there. When it is in the Fixed band, the radar's transmitted spectrum is pure enough not to produce adjacent-channel interference for listeners in the Broadcast bands or for amateur broadcasters.

The method of selecting a radar operating frequency includes monitoring to determine whether any other potential user is currently occupying the frequency. However, because one of the characteristics of HF sky-wave propagation is that a signal can skip over a particular receiving location, monitoring at one place does not guarantee that a channel is unoccupied throughout the world. Thus, the radar could be operated on a frequency occupied by a Fixed transmitter; when that occurs, the radar could interfere with reception at the intended receiver. Both the intended signal and the radar's signal will typically propagate by sky wave. Because the single Fixed receiver might be anywhere on earth, no general way exists for determining whether the radar's signal will reach it. Even if the radar's signal does reach it, no general way exists for determining the power of the desired signal or the power of the radar's signal; thus, it is impossible to predict whether interference with reception of the desired signal will occur. Operation of the ERS in this manner for approximately a year resulted in no reports of interference.

If the radar were inadvertently operated on a channel in use in the International Broadcast bands, interference with an unknown number of broadcast listeners at unknown locations throughout the world would be possible. Whether the interference would actually occur would depend on the relative strength of the broadcast and radar signals at each of the potentially interfered-with receivers, which is, in the general case, not predictable. However, the ERS operated with no reports of interference within the International Broadcast bands.

4.13.2.2.1.2 Services Adjacent to the OTH-B Radar Frequencies

The Amateur Radio Service is allocated four bands that are adjacent to Fixed bands in which the OTH-B radar will operate. These HF bands are used by amateur broadcasters for worldwide communications. The radar

will not be operated close enough to the adjacent bands to produce interference there. Although amateurs were invited to provide the Air Force with reports of hearing the ERS signal, whether it was interfering with them or not, no such reports were ever received.

The Broadcast bands are also typically adjacent to some of the Fixed bands in which the radar is expected to generally operate. So, too, are various bands allocated to the Maritime Mobile and Aeronautical Mobile Services, and to standard time and frequency services. The radar will remain sufficiently far from the band edges that no adjacent-channel interference with users of these bands should occur.

4.13.2.2.1.3 <u>Services Harmonically Related to the OTH-B Frequencies</u>

The harmonics of the OTH-B signal are integer multiples of the desired, or fundamental, frequency. As such, they are typically at frequencies that will not propagate by sky wave to distant regions. Thus, any interference effects would be strictly local. Among the systems that might suffer interference from the radar's harmonics are television, land mobile radio, air-to-ground radio, and VHF (very high frequency) omnirange (VOR) air navigation beacons.

The region of the CRS transmit study areas is not rich with broadcast TV signals. Although no survey has been undertaken, TV viewers near the Amherst, South Dakota, transmit study area probably obtain their strongest signals from KDLO (channel 3) and from KABY (channel 9); KDLO transmits from a 1,705-ft tower, and KABY from a 1,288-ft tower. The strongest TV signal near the Wheaton, Minnesota, transmit study areas is probably that of KCMT (channel 7), which transmits from a 1,130-ft tower near Alexandria, Minnesota, but residents of that area probably also receive KDLO and KABY well. Very likely, some TV reception is possible from other stations, such as those near Fargo, even though all study areas are beyond the "Grade-B" coverage contours of any other TV stations. These lower-level TV signals would be the ones most likely to experience interference.

At this time, not enough information regarding the TV environment or the location of the OTH-B transmit site is available to justify attempting to predict the relative strength of the TV and radar signals at a TV receive antenna.

Measurements in Maine in the vicinity of the ERS indicated that at distances of 6 miles or more from the radar, the radar's harmonics that could potentially interfere with TV were much weaker than predicted, and were generally so weak that they were not detectable above the background radio noise. If interference resulting from the radar's operation on certain subharmonics of the TV signals were to occur in South Dakota or Minnesota, the radar operators would be able to remedy the situation. They would determine those subharmonics, and the radar could be restricted from transmitting on them, just as certain other frequencies are already excluded.

Because low-band VHF land mobile radio operates at frequencies in the band between roughly 30 and 50 MHz, it might be susceptible to interference from OTH-B signal harmonics. Measurements at the ERS suggested that harmonic interference was unlikely at distances greater than about 3 or 4 miles, and a similar prediction applies for the CRS. Experience at the ERS includes a paper company that operated 50-MHz transceivers within several miles of the ERS without experiencing interference. In addition, as the radar was operating, a pair of high-band VHF handy-talkies were used without interference for communicating between the radar building and points about 2,000 ft directly in front of the radar. These units used a frequency of 154.6 MHz, however, which was not a harmonic of any of the radar frequencies used at that time. If the radar's harmonics do produce interference with any established land mobile systems in the area, the offending frequencies could be determined and their use by the radar prohibited. Other mitigating measures are also possible.

The VHF air-mobile communication frequencies in the 118- to 132-MHz band may be susceptible to fifth and higher harmonics. No complaints of interference with airborne communications occurred during ERS operation. However, if such problems occurred at the CRS site, the offending frequencies could be determined and excluded from use.

Radio-operated aids to air navigation include VOR and VORTAC (combined VOR and tactical air navigation [TACAN]) ground stations and the associated receiving equipment in aircraft. VORs transmit on frequencies in 108- to 118-MHz band, and aircraft use the signal to determine their bearing to the VOR. Seven VOR and VORTAC ground stations are within about 100 miles of the CRS transmit study areas; aircraft using them would sometimes be illuminated by the CRS, and their VOR receivers would be potentially susceptible to interference from the radar's fifth and higher harmonics. Measurements conducted in cooperation with the Federal Aviation Administration (FAA) at the ERS indicate that such interference may render a VOR unusable when aircraft are within about 30 miles of the front of the radar. This again, is, a potential harmonic problem that would result from operation of the radar only on certain frequencies. These frequencies could be determined and the radar excluded from using them. Alternatively, the FAA could change the frequencies of the VORs so that they would not be susceptible to interference from the radar.

At least seven nondirectional beacons (NDBs) are located at smaller airports within about 100 miles of the study areas. They transmit within the 200- to 1600-kHz bands, and receive their signals using onboard directional antennas to estimate the direction to a particular beacon. No interference is expected beyond the immediate vicinity of the CRS because these frequencies are significantly below the OTH-B frequency range.

4.13.2.2.1.4 Other Radio Services

Operation of the CRS is not expected to interfere with reception of broadcast radio beyond about 2 miles from the transmit site. The Air Force monitored AM and FM radio broadcasts on an automobile radio at a number of locations near the transmit site while the ERS was operating. They determined that ERS interference with the AM or the FM broadcast bands occurred at distances greater than about 1 mile from the transmitting antenna array.

4.13.2.2.2 Effects on Pacemakers, Electroexplosive Devices, and Fuel Handling

A design susceptibility threshold of 200 V/m (the electric field equivalent to a pulse power density of 10 mW/cm^2) was suggested for cardiac pacemakers in a 1975 draft standard by the Association for the Advancement of Medical Instrumentation. A pacemaker is more likely to react to a pulsed field than to a continuous wave (CW) field because since it could confuse the pulses with the naturally occurring electrical signals that it is designed to sense.

The Air Force conducted measurements of pacemaker susceptibility to RF fields in the HF band in 1977, using a CW signal at 26 MHz. That signal is probably quite similar to the OTH-B linear FM-CW signal, which is essentially continuous (and not pulsed). The Air Force tested 30 pacemakers, of which 17 were unaffected by fields as high as 850 V/m--the maximum field available from the test system. The susceptibility thresholds of the other pacemakers ranged from a high of 850 V/m to a low of 230 V/m. These data suggest that modern pacemakers would be affected by OTH-B electromagnetic fields only if the fields considerably exceeded 200 V/m.

At ground level in front of the CRS, fields would fall below 200 V/m at a distance of about 1,300 ft from the center of the array; behind the array, fields would fall below 200 V/m at about 130 ft. The exclusion fence would be located in front of the arrays at such a distance that a person approaching the radar would not be subjected to fields exceeding about 25 V/m; therefore, the radar should present no hazard.

In the air in front of the radar, the fields would fall below 200 V/m at a slant range of about 1,300 ft or a horizontal distance of about 1,100 ft. Again, this region would be well within the exclusion fence, so that it is highly unlikely that a pacemaker owner would ever enter it. Although operation of the radar would not constitute a hazard to pacemaker owners, the Air Force will arrange with the FAA to publish an appropriate Notice to Airmen (NOTAM) to caution them.

Air Force Technical Manual T.O. 31Z-10-4, on electromagnetic radiation hazards, instructs that fuel handling operations (e.g., fueling of aircraft) should not be undertaken in electromagnetic fields with pulse power density greater than 5,000 mW/cm^2. The fields in question are

typically those of conventional radars, for which the pulse power is much greater than the average power. The OTH-B radar does not pulse like a typical radar; rather, it operates continuously. Its "pulse" power density and average power density are equivalent, providing that the average is taken over a time duration no greater than the time that the radar's beam is pointed in any given direction. The OTH-B power density, even in the near-field column, never exceeds about 258 mW/cm^2, which is a factor almost 20 lower than the maximum safe power density of 5,000 mW/cm^2. Thus, the CRS would not pose a hazard to existing or planned fuel handling operations.

The Air Force also has a standard for determining safe separation distances between radars and areas where electroexplosive devices (EEDs) are stored, handled, or transported. Probably the most common EED is the electric blasting cap. At the recommended safe separation distances, EEDs are considered definitely safe, which does not imply that they are definitely unsafe at slightly shorter distances. In fact, the power density required to fire an EED is perhaps 100 times greater than the density used to define the safe separation distance.

The safe separation distances are determined by certain ground-wave power density thresholds, which, for a given transmitter power are highly dependent on the electrical conductivity of the ground. For the CRS, predictions of power density were based on the high ground conductivity associated with "marsh land," and they may overestimate the actual power density by an as-yet-unknown amount. As a result, the safe separation distances discussed below are probably also greater than necessary by an unknown amount. The distances discussed below should be regarded as conservative figures. The eventual safe separation distances may be smaller.

The OTH-B radar would present no hazard to EEDs stored or being transported in metal containers at ground level at distances beyond about 1,300 ft from the array center. EEDs stored or being transported in nonmetal containers would definitely be safe at distances greater than roughly 2.3 miles in front of the radar or about 1,300 ft behind it (based on relatively high ground conductivity). If the ground conductivity were lower, the corresponding safe distances would be smaller. Only military aircraft are likely to be equipped with EEDs. Aircraft in flight, carrying or equipped with EEDs, would be beyond the hazardous area if they were more than about 1,300 ft from the front of the radar. They will be warned by a NOTAM. Thus, although storage or transport of EEDs in metal containers would be safe anywhere outside the 4,000-ft exclusion fence; those in nonmetal containers would not be guaranteed safe unless removed to considerably greater distances.

The safe distance for handling EEDs in preparation for blasting would be determined for the selected transmit site based on ground conductivity measurements and actual power density measurements. Until that time, the following calculated distances would be used to define the safe separation distance: If the ground conductivity is as high as

the assumed value, the distance beyond which EEDs may be safely handled in preparation for blasting is 4 miles. (The Institute of Makers of Explosives in its booklet on the safe handling of blasting caps recommends a 17-mile distance, but does not discuss ground conductivity; this is an extremely conservative distance and is probably based on a very high ground conductivity.) At the ERS site, the calculated safe distance was less than 3 miles because of the somewhat lower conductivity of the soil in Maine. When the safe separation distances have been determined, the Air Force will notify surrounding land owners and state and local government offices to allow them to take appropriate actions.

4.14. Human Health Effects

4.14.1 Introduction

4.14.1.1 Background

4.14.1.1.1 Definition of RFR

"RFR" is used as a generic term to include other terms commonly found in the published literature on bioeffects, such as electromagnetic radiation (EMR), nonionizing electromagnetic radiation (NIEMR), electromagnetic fields (EMF), radiofrequency electromagnetic (RFEM) fields, microwave radiation, microwave fields, and others. The center (carrier) frequencies of the OTH-B radar vary from 5 to 28 MHz, which are entirely within the 3- to 30-MHz high-frequency (HF) band. The waveform is of a frequency-modulated (FM) nature. Thus, even though the bioeffects literature encompasses studies from direct current (DC) to 300 GHz, with both unmodulated and modulated frequencies, the frequency range of primary interest here is approximately from 10 kHz to 30 GHz. Outside this range (e.g., at power line frequencies), the mechanisms of interaction are substantially different. As noted in Appendix B, the maximum anticipated revisit time for the OTH-B beam to return to a given direction is 80 seconds. This is much less than the 6 min averaging time designated in Section 4.14.1.3. Therefore, the following sections on health hazards use average power densities, but also consider pulse powers and modulation effects where so indicated by the literature.

4.14.1.1.2 The Problem

The basic issue is whether brief or continual exposure of people to the RFR produced by the CRS transmit antenna arrays is likely to affect their health adversely. Because the CRS receive antenna arrays do not emit RFR, it is not considered further in this section.

A critical review of the present state of knowledge regarding biological effects of RFR serves as the primary reference for the human health aspects of this assessment of CRS. This review is "Bioeffects of Radiofrequency Radiation: A Review Pertinent to Air Force Operations," by L. N. Heynick and P. Polson (1983). The review is being updated and expanded and when complete will be issued as "Critique of the Literature on Bioeffects of Radiofrequency Radiation: A Comprehensive Review Pertinent to Air Force Operations," by L. N. Heynick (in process). These reviews do not contain information about specific systems, but include studies covering the frequency range of the OTH-B radar. The discussion and conclusions presented below regarding possible RFR-bioeffects of the OTH-B radar were derived by considering the research results that are most significant scientifically and also pertinent to the operational characteristics of the OTH-B radar and to the RFR power densities outside the exclusion fence.

The organization of the subsections below, starting with "Problems of Risk Assessment," (4.14.1.2) parallels the corresponding sections of the 1983 review. By removing the prefix 4.14 from the subsection numbers, the corresponding section numbers in the review are obtained. The subsections below repeat appropriate parts of the review, (e.g., section summaries and overall conclusions), but bibliographic references have been removed and other minor changes have been made. This parallel arrangement permits use of this assessment as a complete document without the need to refer to the review unless the reader desires more detail or the reference citations.

Exposure of humans to RFR from the CRS transmit arrays can occur under two circumstances. First, people may be airborne near the transmit site. In that event, they may be exposed to the main beam or sky wave. Second, persons outside the exclusion area may be exposed to the low-intensity RFR existing near the ground (surface wave). (Possible exposure of individuals within the exclusion area is not considered because the Air Force will provide appropriate protective and control measures.)

4.14.1.1.2.1 <u>Exposure While Airborne</u>

Exposure of people in airplanes to the main beam is a possibility shared with many operational high-power radar systems, including experimental versions of the OTH-B system proposed for the CRS. However, no case of harm to humans from any such incidental exposure is known, and there is no reason to believe that the OTH-B situation would be different from that of other radar installations in this respect.

Regardless of the final CRS transmit site, the Air Force will request the FAA to issue a formal NOTAM to avoid the transmit site and an appropriate volume of airspace near it. Federal regulations governing general aviation require that airplanes maintain a minimum altitude of 500 ft over population centers and 1,000 ft over dense gatherings of people, such as in a stadium. In sparsely populated regions such as the

present study areas, there are no altitude restrictions. Thus, it is possible that, even with a formal NOTAM, persons in small aircraft might occasionally fly past the transmit site and be exposed to the RFR for periods of about 1 min or less. Calculations indicate that if an airplane flew at a constant altitude of 500 ft toward the antenna, the airplane would be exposed, at most, to a maximum instantaneous power density of about 3.5 mW/cm^2 under band F conditions. Similar calculations for an altitude of 1,000 ft yield a maximum instantaneous power density of about 0.9 mW/cm^2. A time-averaged power density greater than 1 mW/cm^2 would occur within about 1,500 ft of the antennas. However, the likelihood of aircraft flying so close is small, and the duration of exposure to such power densities would be brief. Further, a metal aircraft skin would provide considerable protective shielding. Consequently, it is most unlikely that people within the aircraft would suffer any health effects directly related to RFR exposure.

Humans can perceive pulsed RFR of appropriate characteristics as apparent sound. In animals, pulsed RFR may also produce other effects related to the pulse characteristics per se, such as changes in behavior and alterations in the blood-brain barrier. However, none of these effects would be of concern with regard to the OTH-B radar because it uses FM-CW rather than pulsed RFR.

Because of these considerations, this assessment gives no further attention to possible exposures of people in aircraft flying through the main beam of the CRS.

4.14.1.1.2.2 Near-Ground-Level Exposure

The location of the exclusion fence would ensure that the highest average power density at ground level immediately outside the exclusion area in any direction would not exceed the 1982 ANSI radiation protection standard for the general population for the OTH-B frequency range. As distance from the transmit site increases, the ground-level power densities would decrease (see Appendix B) to even smaller values.

4.14.1.1.3 Data Base and Literature Selection

Under Air Force sponsorship, SRI International has compiled a data base of over 200 detailed reviews and analyses of research projects on RFR bioeffects published in various scientific journals and reports. Other sources for this review included the previously mentioned review of RFR bioeffects published by the Air Force, a comprehensive review by the U.S. Environmental Protection Agency (EPA), bibliographies in previous reviews of the literature, and several comprehensive bibliographies prepared by U.S. government personnel or by other organizations under government sponsorship.

Several criteria were used in selecting articles for this review. Complete, peer-reviewed papers published in scientific journals or in proceedings of scientific symposia were preferred. Initially, abstracts of presentations at scientific symposia were also selected if they included adequate details of the procedures and findings. However, full reports of such studies frequently failed to appear in the peer-reviewed literature, presumably because critical peer review revealed problems with the work. Peer review therefore became the most important criterion.

Other criteria included the date of publication (those articles that were most recent were preferred because of improvements in experimental methodology and in the technology of exposure and dose measurement), and the significance of the findings to human health (e.g., studies of human populations to find out whether the occurrence of specific effects is statistically higher in population samples exposed to RFR than in similar population samples not exposed, and experiments involving long-term exposure of animals). Other criteria included the relevance of an article to others on the same topic and possible relevance to concerns expressed by citizens' groups.

Most RFR bioeffects are frequency-dependent but not frequency-specific per se. Rather, the frequencies of the incident RFR (together with its average power density and polarization and the size, shape, and orientation of the biological entity) determine the rate of energy absorption and its internal distribution. Another criterion for selection was therefore the frequency involved. Rather than including only articles involving frequencies close to those of specific systems, selection extended to include those involving frequencies over the general range from 10 kHz to 30 GHz. (As noted earlier, the mechanisms of interaction become somewhat different above and below these approximate limits.) Resource constraints necessarily limited the number of articles selected. However, the articles selected are representative of the many reports on the biological effects of RFR appearing in the scientific literature.

4.14.1.1.4 Eastern European Bioeffects Literature

Probably the most controversial aspects of research on the biological effects of RFR are (1) the large discrepancies between results, at low levels of RFR, reported in the Eastern European literature and those obtained in Western countries such as the United States, and (2) the basic differences in philosophy between the two groups of countries in prescribing safety standards or guidelines for the protection of humans against possible hazards from RFR exposure.

From the end of World War II to about the late 1960s, few of the scientific reports on bioeffects research in the USSR (or other Eastern European countries) were amenable to critical review because they lacked essential information. In the early 1970s, starting with an international conference in Warsaw on the RFR bioeffects in 1973 under the

joint sponsorship of the World Health Organization (WHO), the U.S. Department of Health, Education, and Welfare (HEW), and the Scientific Council to the Minister of Health and Social Welfare of Poland, international exchanges of information increased materially, and translations of Eastern European articles became easier to obtain. Because most of the Eastern European documents published before 1973 (and many since then) are merely abstracts that contain no details of the experimental method, number of subjects, or analytical approach used in the study, evaluation of them proved difficult. More recent Eastern European studies contain more detail. The review cites and analyzes some of them.

4.14.1.1.5 Present Climate and Context

4.14.1.1.5.1 Proliferation of RFR Emitters

Public use of RFR-generating devices and acceptance of their benefits have been growing almost exponentially over a number of years. Contributing to the expansion of RFR use in this country are public TV and radio broadcasting stations, ham radio transmitters, citizens-band radios, ground-level and satellite communication systems, civil and military aircraft navigation systems, airport traffic-control systems, medical diathermy units, defense tracking systems, weather radar systems, remote garage-door-opening devices, microwave ovens, and a variety of units for industrial heating and processing of materials.

The federal government regulates use of all of these devices, mainly through the FCC, restricting their operation to specific frequency bands and limiting the power levels that most devices may emit. Still, as the number of such devices increases, the background level of RFR is bound to increase as well, particularly in urban and industrial centers. The question continually arises whether this increasing level of RFR will be deleterious to human health.

Various agencies of the federal government have established programs to deal with the question of RFR effects on human health. The Air Force has taken an active role for more than 25 years in advancing the state of knowledge of RFR bioeffects to ensure safety to the general population from its operations and to establish personnel-exposure regulations. The U.S. Army and Navy also maintain research programs on the biological effects of RFR. The EPA conducts programs to measure environmental levels of RFR and to assess in the laboratory the biological effects of RFR, and has published a comprehensive review of the literature. The Center for Devices and Radiological Health (formerly the Bureau of Radiological Health) has promulgated a performance standard for permissible microwave oven leakage. The National Institute for Occupational Safety and Health (NIOSH) is investigating the use of industrial RF and microwave devices and has published a draft of its recommended occupational exposure standards. The results of these programs indicate that the biological effects of RFR occur, with limited

exceptions, only at average power densities exceeding about 1 mW/cm^2. Further, present maximum environmental levels in cities are in the range of 0.00001 to 0.005 mW/cm^2, with the occasional exception of regions in the immediate vicinity of broadcast towers, where environmental levels may range from less than 0.01 to more than 0.2 mW/cm^2.

In summary, the use and benefits of RFR devices for communications, radar, personal and home use, and in industry are widely accepted. On the other hand, the proliferation of the use of RFR devices, including various military radar and communications systems, raises concerns with many people that some as-yet-undefined hazardous biological effects may be associated with this proliferation. The EIS addresses such concerns with regard to the OTH-B radar.

4.14.1.1.5.2 Measurements of Environmental Levels of RFR in Selected U.S. Cities

The EPA has measured the environmental field intensities at selected sites in various U.S. cities. In two reports, EPA investigators discuss the results for the 15 cities (a total of 486 sites) studied. The sites in each city were selected to permit estimations of cumulative fractions of the total population being exposed at or below various average power densities, based on the population figures for the 1970 census enumeration districts.

The frequency bands from 54 to 890 MHz were included in the analyses. Field strengths measured at each site were integrated over these bands and converted into equivalent average power densities. The site values in each city were then used with the population figures in the various census enumeration districts in a statistical model. The model was designed to estimate the population-weighted median exposure value for that city and to calculate other statistics of interest. These median values range from 0.000002 mW/cm^2 (for Chicago and San Francisco) to 0.000020 mW/cm^2 (for Portland, Oregon). The population-weighted median for all 15 cities is 0.0000048 mW/cm^2. The percentage of the population of each city exposed to less than 0.001 mW/cm^2 ranges from 97.2% (for Washington, D.C.) to 99.99% (for Houston, Texas), with a mean value for all 15 cities of 99.4%. The major contributions to these exposure values are from the FM-radio and TV broadcast stations.

The EPA also measured RFR levels at sites close to single or multiple RFR emitters. Typical locations included the bases of transmitter towers and the upper stories (including the roof) of tall buildings or hospital complexes close to transmitter towers. At the base of an FM tower on Mt. Wilson, California, for example, the fields ranged from 1 to 7 mW/cm^2, but such values are believed to be uncommon. Most measurements in tall buildings close to FM and TV transmitters yielded values well below 0.01 mW/cm^2. A few values, however, were close to or slightly greater than 0.2 mW/cm^2 (e.g., 0.23 mW/cm^2 on the roof of the Sears Building, Chicago).

4.14.1.2 Problems of Risk Assessment

Assessing risk to human health and setting standards to protect health are extremely complex problems. In addition to purely technical and scientific questions, there are problems involving philosophy, law, administration, and the feasibility of programs that are still only vaguely recognized. It is clearly beyond the scope of this document to deal with those subjects in detail, but it is important that they be mentioned. Three aspects of risk assessment need to be considered: the scope of biological effects evaluated in setting standards, the overall approach to setting standards, and standards of protection from overexposure to RFR in the United States, the USSR, and other countries.

Alternative approaches to determining the acceptable degree of risk or undesirable effect can be illustrated by comparing occupational air pollution standards that prevailed until recently in the USSR and the United States. In the USSR, maximum allowable concentrations (MACs) for airborne noxious agents are set at a value that will not produce any deviation from normal in physiological parameters, or any disease in anyone exposed to the agent (occupational or general population). In the United States, threshold limit values (TLVs) for airborne noxious agents are set to ensure that nearly all workers can be exposed regularly during the working day without adverse effect. The differences stand out clearly: in the USSR, all biological effects are considered without regard to their medical significance or the possibility of human adaptation, and the values of MAC selected must, in principle, protect the most susceptible member of the population. In the United States, only harmful effects are considered, and protection is not extended to the most susceptible workers, except that a safety factor is generally included in the TLV so that an adverse reaction in an individual can be detected before serious medical consequences ensue.

Both approaches are predicated on the existence of a threshold concentration; that is, on a concentration below which no biological effect will occur. In the absence of a true threshold, the extent of protection to give to the population can only be weighed against the cost and technical feasibility of providing that protection. Making such choices is the function of risk-benefit analysis in the assessment of environmental hazard.

The existence or nonexistence of thresholds has been debated at length, but much of the debate has been based on opinion rather than evidence. As a practical scientific matter, thresholds for noxious or deleterious effects must exist for at least some substances because many naturally occurring substances are essential to life at one concentration and highly toxic at higher concentrations. In this document, the possible existence of threshold levels for RFR effects is considered on a case-by-case basis, with due regard for the physiological mechanisms of effect.

4.14.1.3 Exposure Standards

The term "exposure standards" is generally applied to specifications or guidelines for permissible occupational or nonoccupational exposure of humans to electromagnetic fields. The standards are expressed as maximum power densities or field intensities in specific frequency ranges and for indicated exposure durations.

In 1982, ANSI Subcommittee C95.4 adopted a frequency-dependent standard for both occupational and general-public exposure to RFR to replace the ANSI Radiation Protection Guide of 10 mW/cm^2 published in 1974 (ANSI, 1982). The 1982 ANSI standard, shown in Table 4-4 was derived from analyses of a large number of recent representative experimental and theoretical results selected by a subcommittee of ANSI C95.4. It covers the frequency range from 300 kHz to 100 GHz and is based on a mean whole-body specific-absorption-rate (SAR) limit of 0.4 W/kg instead of a constant incident power density. SAR is defined as the rate at which radiofrequency electromagnetic energy is imparted to an element of mass of a biological body. The lowest limit, 1 mW/cm^2, is for the range from 30 to 300 MHz, within which RFR absorption by the human body as a resonant entity is highest. The value 0.4 W/kg includes a safety factor of 10, and the specified limits are not to be exceeded for exposures averaged over any 0.1-hr period.

Table 4-4

1982 ANSI RADIOFREQUENCY RADIATION PROTECTION GUIDES

Frequency Range (MHz)	E^2 (V^2/m^2)	H^2 (A^2/m^2)	Power Density (mW/cm^2)
0.3 - 3	400,000	2.5	100
3 - 30	4,000 ($900/f^2$)	0.25 ($900/f^2$)	$900/f^2$)
30 - 300	4,000	0.025	1.0
300 - 1,500	4,000 (f/300)	0.025 (f/300)	f/300
1,500 - 100,000	20,000	0.125	5.0

Note: f is the frequency in MHz.

In the far-field of an RFR source, the governing maximum values are the power densities shown in column 4 of Table 4-4, and the corresponding squares of the electric and magnetic field amplitudes (E^2 and H^2) in columns 2 and 3 are approximate "free-space" equivalents.

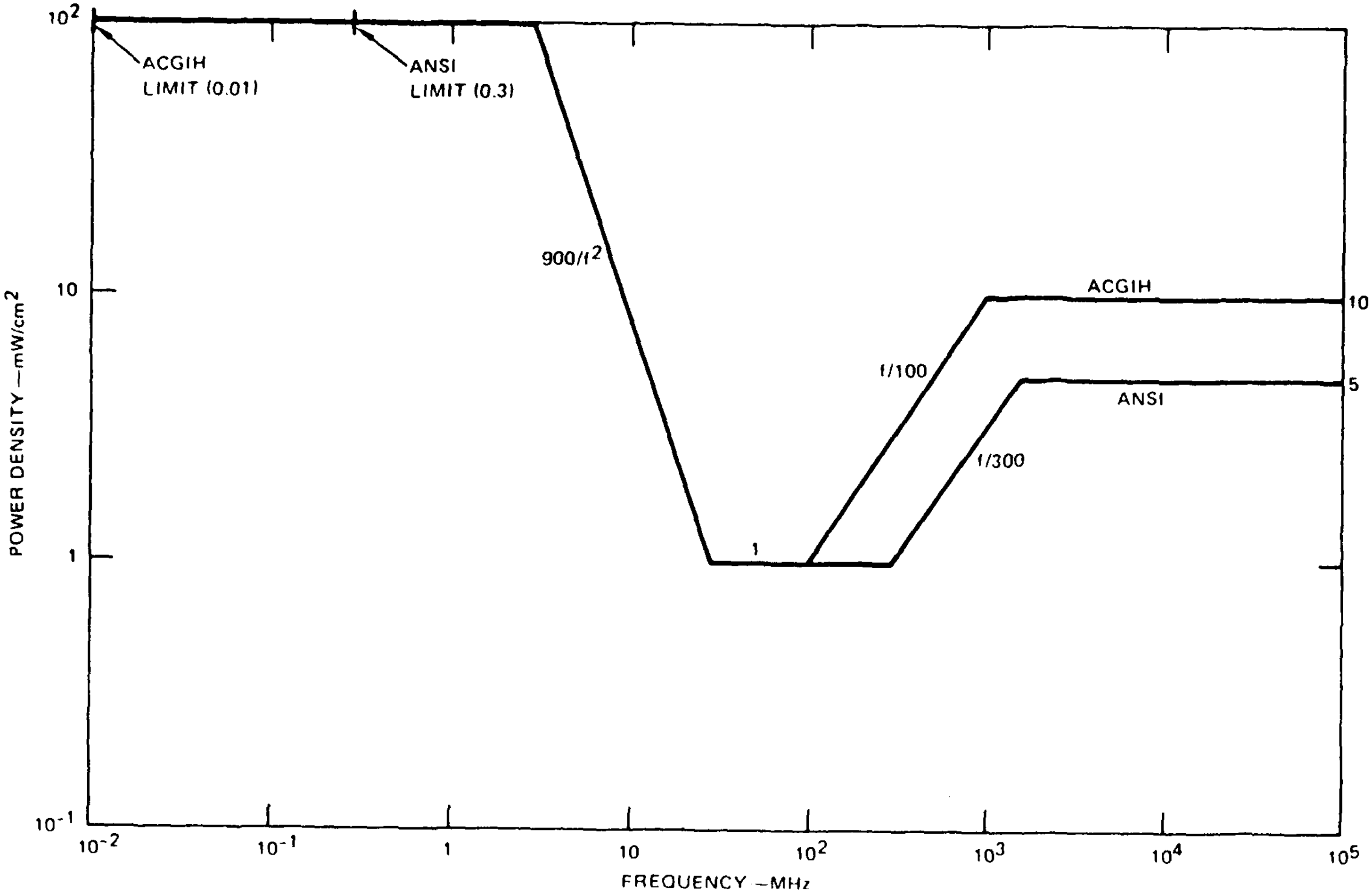
In the near field of an RFR source, the governing maxima are the values of E^2 and H^2, but can be expressed in terms of corresponding power densities.

The ANSI power density limits for the OTH-B 5- to 28-MHz range are 36 to 1.15 mW/cm^2.

In 1983, the American Conference of Governmental Industrial Hygienists (ACGIH) published new threshold limit values for RFR. These are also based on 0.4 W/kg, but for occupational exposures only. The ACGIH threshold limit values are displayed graphically in Figure 4-2 for comparison with the ANSI values. The major difference is that the 1 mW/cm^2 value extends only from 30 to 100 MHz and rises from the latter with a slope f/100 to 10 mW/cm^2 at 1 GHz. This difference is based on the premise that children, who have higher whole-body resonant frequencies than adults, are unlikely to be occupationally exposed to RFR. Another difference is that the lower frequency limit for the ACGIH standard is at 10 kHz instead of 300 kHz.

The currently applicable Air force permissible exposure limits (PELs) are given in AFOSH Standard 161-9. For exposures averaged over any 0.1-hr period to frequencies between 10 MHz and 300 GHz, the PEL is 10 mW/cm^2, and from 10 MHz down to 10 kHz, the PEL is 50 mW/cm^2. For exposure within any 0.1-hr period, the product of the power density and the exposure duration shall not exceed 3,600 mW-s/cm^2 for frequencies between 10 MHz and 300 GHz, or 18,000 mW-s/cm^2 for frequencies between 10 kHz and 10 MHz. This standard is being revised: Currently proposed PELs for exposure, during any 0.1-hr period, of adults of normal size (55 in. or more tall) are the new ACGIH values, and the PELs for exposure of short humans (less than 55 in. tall) are the new ANSI values, but extended down to the ACGIH lower frequency limit of 10 kHz. For the 5-28 MHz range, the new PELs for humans of both normal and small size are the same as the new ANSI values.

An exposure standard for the general (nonoccupational) population was proposed for internal consideration by the EPA in 1984. This standard was to be 10 times stricter than the 1982 ANSI guidelines, but was not issued because of conflicts within the agency, particularly concerning the inability to enumerate actual adverse health effects in the population resulting from RFR exposure. The matter is apparently still under review.



*Based on average SAR limit of 0.40 W/kg in exposed tissue.

SOURCES: ANSI, 1982; SRI International

FIGURE 4-2 ANSI AND ACGIH SAFETY GUIDES FOR WHOLE-BODY EXPOSURE OF HUMANS*

On 8 July 1983, the Executive Council of the International Radiation Protection Association (IRPA) approved interim guidelines on limits of exposure to radiofrequency electromagnetic fields in the frequency range from 100 kHz to 300 GHz (Mitchell, 1985). The International Nonionizing Radiation Committee of IRPA included participants from France, the Netherlands, Poland, Denmark, Germany, ~eat Britain, Australia, and the United States. These guidelines apply to RFR exposure of both occupational workers and the general public. The general public values are given in Table 4-5. The basic limits of exposure for frequencies grea'er than 10 MHz are expressed in whole-body averaged SAR.

For practical purposes, derived limits of exposure are also expressed in average incident-power density. The derived limits appear to be conservative in the frequency range 10-30 MHz. The approach, to state the exposure limit in terms of whole-body SAR, represents a departure from current practices (i.e., most new standards express the permissible exposure levels in average incident-power density, even though they are based on limiting the whole-body SAR). For occupational workers, the IRPA exposure limit for frequencies greater than 10 MHz is 0.4 W/kg when averaged over any 6 min and any 1 gram of tissue. For the general public, the IRPA exposure limit is 5 times lower (i.e., 0.08 W/kg when averaged over any 6 min and over the whole body or 0.8 W/kg when averaged over any 6 min and any 1 gram of tissue).

Table 4-5

IRPA GENERAL POPULATION RFR EXPOSURE LIMITS

Frequency (MHz)	E (V/m)	H (A/m)	Power Density (mW/cm^2)
0.1 - 1	87	0.23	2
1 - 10	$87/f^{1/2}$	$0.23/f^{1/2}$	2/f
10 - 400	27.5	0.073	0.2
400 - 2,000	$1,375f^{1/2}$	$0.0037f^{1/2}$	f/2,000
2,000 - 300,000	61	0.16	1

These standards are based on the same assumption--that 4 W/kg is a reasonable threshold for adverse biological effects. Differences in the permissible incident-power densities as a function of frequency result from the degree of conservatism applied in each instance.

The IRPA general population power density limits for the OTH-B 5- to 28-MHz range are 0.4 to 0.2 mW/cm^2.

Exposure limits in the USSR are considerably lower than those of Western countries, especially the limits for general population exposure. Such standards are apparently based on their philosophy that exposure to power density levels that cause relatively small changes from normal mean values is potentially harmful. Until recently, the maximum level for 24-hr exposure of the general population was 0.005 mW/cm^2, and the occupational standard was as summarized in Table 4-6. This table specifies higher maximum levels than those for the general population. For example, for the 10- to 30-MHz range, an electric field intensity limit of 20 V/m is specified for exposures for a full working day. The free-space equivalent power density is 0.11 mW/cm^2. This standard provided no limit for frequencies below 10 MHz.

Table 4-6

MAXIMUM PERMISSIBLE LEVELS FOR OCCUPATIONAL EXPOSURE, USSR

Frequency (GHz)	Exposure Duration	Exposure Limit	Remarks
0.01 to 0.03	Working day	20 V/m	--
0.03 to 0.05	Working day	10 V/m 0.3 A/m	--
0.05 to 0.3	Working day	5 V/m 0.15 A/m	--
0.3 to 300	Working day	0.01 mW/cm^2	Stationary antennas
--	Working day	0.1 mW/cm^2	Rotating antennas
--	2 hr	0.1 mW/cm^2	Stationary antennas
--	2 hr	1 mW/cm^2	Rotating antennas
--	20 min	1 mW/cm^2	Stationary antennas

Source: Stuchly and Repacholi, 1978.

Recent U.S. visitors to the USSR have reported pending and/or adopted revisions to the above standards. For 24-hr exposure of the general population, the maximum level has been increased from 0.005 to 0.010 mW/cm^2. The USSR also appears to be developing standards for specific types of RFR emitters. As examples, for a specific radar that emits 1-microsecond pulses of 10-cm (3-GHz) RFR at 3 pulses/sec, the exposure limit is 0.015 mW/cm^2 (average power density), and for microwave ovens, the maximum value at a distance of 50 cm is 0.010 mW/cm^2. For occupational exposures in the frequency range from 0.3 to 30 GHz and exposures of 0.2 hr or longer, the product of the average power density and the exposure duration should not exceed 0.2 mW-hr/cm^2. Thus, the exposure limit for an 8-hr working day has been increased from 0.010 to 0.025 mW/cm^2, the limit for 2-hr exposure is 0.1 mW/cm^2 (no change), and the 1 mW/cm^2 limit is for exposures of less than 12 (instead of 20) min. Though not stated expressly, by implication, these changes are applicable to RFR from stationary antennas; no information regarding rotating antennas was obtained. The limits for the frequency ranges 0.03 to 0.05 GHz and 0.05 to 0.3 GHz are unchanged. Again, there do not appear to be exposure limits for the range below 10 MHz.

The exposure limits in Poland and Czechoslovakia are higher than those of the USSR, but lower than those of the Western countries.

For general interest, the standards of Canada and Sweden and standards adopted or proposed by several state, county, and municipal governments in the United States are discussed in the review.

The average power density outside the exclusion fence around the CRS transmit array would be less than 0.02 mW/cm^2; that is, one-tenth the level specified by IRPA for continuous general population exposure in this frequency band. The values at population centers near this transmit site are less than the new USSR standards for general population exposure.

4.14.1.4 Assessment of Scientific Information

In an assessment of the potential biological effects of RFR from a specific system, it is necessary to consider certain quantitative relationships among (1) the physical parameters of the RFR such as frequency, power density, and polarization; (2) the mechanisms of absorption and distribution of energy within the biological organism; and (3) the resulting biological effects as measured by some functional or anatomic alteration. Like all scientific theory, the body of biophysical theory that links these three factors has been synthesized from a variety of experimental evidence. The theory is subject to refinement or revision as valid new evidence is accumulated that is inconsistent with the theory. Nevertheless, it furnishes the context in which new experimental evidence is considered.

Obviously, the most directly applicable experimental evidence concerning possible bioeffects of any specific system would come from experiments in which humans were exposed to its specific frequency range and likely power density values. Furthermore, the best evidence would come from quantitative evaluation of a large number of biological endpoints. Such data, however, do not exist. The relatively small amount of data on human exposure to RFR have primarily been derived from epidemiologic studies conducted after exposure. However, such studies are rarely adequate because the numerical values of the exposure parameters for most epidemiologic studies are not known in detail, and the unexposed control group of people selected for comparison may differ significantly from the exposed population in factors other than exposure to RFR. Most available information is indirect because it is derived primarily from experiments with animals and requires at least some extrapolation of species, field characteristics, duration of exposure, and biological effects.

Regardless of the particular line of evidence being considered, certain concepts and constraints affect the interpretation. In particular, scientists disagree over whether an effect, especially one that is reversible or compensable, constitutes a hazard. Furthermore, only rarely is any particular study subjected to confirmation by the performance of an identical experiment by another investigator. More often, an analogous--but not identical--experiment is conducted with the objective of clarifying or expanding the results of the initial experiment. The second experiment ideally provides a better means of incorporating the findings into the theory that underlies the body of knowledge in a particular field of investigation, but it does not necessarily confirm the results of the first investigation.

Still another consideration is also important: scientific findings are probabilistic in nature, in that facts are known only to some level of probability for a given population; the applicability of those facts to a particular individual may be constrained. For example, the term "median effective dose" for a certain agent refers to the dose that will elicit the response characteristic of that agent in one-half of the exposed individuals. Before the dose is administered, however, one cannot predict whether any specific individual will respond, although the prediction that an individual will have a 50% chance of showing the response is valid. In effect, the probabilistic nature of scientific evidence means that no amount of scientific data can guarantee the absolute safety of any agent for any individual or group of individuals. Analysts disagree over whether the conventional scientific approach, whereby an investigator finds or fails to find a statistically significant (very low probability of chance occurrence) difference between experimental and control groups, is appropriate to considering potential hazards to humans. The scientist's statement that no statistically significant differences between the groups are discernible is not equivalent to the absolute statement that no difference between the groups exists.

Conceivably, agents may have effects that are biologically real but so small in magnitude that the difference in mean response between experimental and control populations may not be discernible within the scattering of values for both populations if the sample sizes are small. Biological studies to detect such small differences and to show that they are statistically significant (to a prespecified probability that they are not due to chance) would require the use of large numbers of animals and, in some cases, long exposure times. The expenditures in time and money necessary to perform such studies may be so large that sponsoring institutions with limited budgets often decide that such studies are not cost-effective in terms of the sponsor's overall objectives. A frequent alterative is to predict effects at very low levels by extrapolation from findings at higher levels, on the basis of assumptions about the mathematical relationship between the level (or dose) of the agent and the degree of the effect. Such assumptions are open to challenge, however, and this approach may lead to disagreement over the possible existence of a threshold dose or dose rate below which the agent has no effects.

It must also be remembered that scientists have personal values, goals, and attitudes. It has been said that there is no such thing as an unbiased expert because becoming an accepted authority involves a personal commitment over a period of time that leads to emphasis of certain viewpoints. Thus, like probabilistic scientific findings, objectivity may well be characteristic of scientists as a group without necessarily being characteristic of any individual scientist. Personal bias can .onsciously or unconsciously affect how the experiment is designed, how the data are interpreted, and particularly, how the results are applied to decision making. The last factor is especially important when the decision to be made is in an area outside the scientist's field of expertise.

Finally, scientific experiments are usually restricted to the evaluation of only one factor. In the real world, however, interactions are far more complex. The effect of combinations of factors is illustrated in the incidence of lung cancer in uranium miners, which is higher than in the general population, presumably as a result of the inhalation of radioactive material. The extent of the increased incidence in nonsmoking miners is marginal, but miners who smoke cigarettes have a much higher incidence of lung cancer than either nonsmoking miners or the general population. Thus, scientific evidence can only supply probabilistic information that is relatively narrow in its application to the real world.

4.14.1.5 Other Reviews

Representative, general reviews of the literature on RFR bioeffects, including several papers by Eastern European authors, are described in Section 1.6 of the review cited ir. Section 4.14.1.1.2, primarily as

background material. Although the conclusions of the authors of those reviews were examined carefully, it is important to note that the conclusions presented below regarding the consequences of human exposure to the RFR from the CRS were derived independently.

4.14.2 Interactions of RFR with Biological Entities

Interactions of electromagnetic fields with biological entities are often loosely characterized in the bioeffects literature as "thermal" or "nonthermal," a usage that has led to confusion and controversy. Therefore, it is appropriate at this point to introduce working definitions of these terms, with the recognition that the boundary between these types of interaction is not sharp.

The interaction of an agent (e.g., RFR) with an entity (biological or nonbiological) can be characterized as thermal if the energy absorbed by the entity is transformed at the absorption site into heat. Heat absorption, in turn, is defined in classical thermodynamics as either an increase in the mean random speed (or kinetic energy) of the molecules at the site (a local increase in temperature), or as an increase in the disorder or randomness of the molecular motion without an increase in mean random speed (a first-order phase change, such as the process involved in ice melting at 0° C), or both.

An entity can also absorb energy at specific discrete frequencies in the form of energy packets or "quanta," each of which has an energy proportional to one of the discrete *frequencies*. Although large numbers of molecules can be involved, quantum absorption is essentially a microscopic phenomenon in that the constituents and configurations of the various molecular species comprising the entity determine the specific frequencies or characteristic spectra at which such absorption can occur. The kinds of interactions involved are numerous and of varying degrees of complexity. They include alterations of molecular orientations and configurations that do not change the basic identities of the molecules, disruption of intermolecular or intramolecular bonds, and excitation of atoms or molecules to higher electron states (including ionization). Such interactions can be characterized as "short-range" processes.

It is theorized that cooperative interactions also occur among subunits of molecules within biological cells, in cell membranes, and in extracellular fluids. Cooperative interactions are often characterized as "long-range" because absorption of energy at one specific site in a structure (e.g., in a membrane or in a biological macromolecule) can affect a process elsewhere in the structure, or a function of the structure as a whole can be triggered by the release of energy stored in the structure, thereby producing biological amplification.

Conceptually, all such quantum interactions can be characterized as "nonthermal." However, if most of the energy thus absorbed is subsequently transformed locally into heat (as defined above), the distinction between nonthermal and thermal is blurred. Pragmatically, therefore, characterization of an interaction of RFR with a biological entity as nonthermal requires that the interaction give rise to a frequency-specific effect that is experimentally distinguishable from heating effects caused by thermalization of the absorbed RFR energy.

4.14.2.1 Thermal Interactions and Specific Absorption Rates (SARs)

Consider now the effects of continuous wave (CW) RFR on a human or an animal. The relative magnetic permeability of most organic constituents is about unity. Therefore, thermal interactions (as defined above) can be described in terms of the dielectric, electrically conductive, and thermal properties of the body organs, tissues, fluids, and so forth, as well as the characteristics of the RFR (frequency, power density, polarization). Measurements of these properties have been made for various mammalian tissues, blood, cellular suspensions, protein molecules, and bacteria over the frequency range from about 10 Hz to 20 GHz. In the subrange from about 300 MHz to about 10 GHz, the dielectric constant of such constituents as skin, muscle, and blood varies little with frequency, and the differences in values among such constituents are largely due to differences in tissue water content. In addition, electrical conductivity increases slowly with frequency in this subrange.

In the frequency range from 3 to 30 MHz (the frequency range of interest for this EIS), the dielectric constant of muscle varies from about 360 to about 110. The values for skin, blood, and other tissues with high water contents are comparable. The values for fat, bone, and other tissues with low water contents are about 10 times smaller and are sensitive to the amount of water the tissues contain.

Because the index of refraction of any material is related to its dielectric constant, RFR is reflected and refracted at boundaries between regions of differing dielectric properties, such as at the surface of a body (whether organic or inorganic), for the same physical reasons as for light at a glass-air interface. Thus, RFR at normal incidence to a relatively thick planar specimen is partially reflected at the surface, and the fraction of the power density entering the specimen suffers progressive attenuation with depth because of energy absorption. The concept of "penetration depth" is often used. For homogeneous specimens, the penetration depth is defined as the distance at which the electric field strength is about 37% of its value or, equivalently, the power density is about 14% of its value just within the surface. The numerical values of penetration depth depend on the electrical properties of the material.

Both the percentage of incident RFR that is reflected and the penetration depth vary inversely with frequency. In the 3- to 30-MHz range, about 95 to 85% of the incident power density is reflected at the air-skin interface, and the approximately 5% to 15% that enters the body is progressively attenuated with depth because of energy absorption in the tissues. The penetration depths for skin, muscle, and other high-water tissues are about 91, 22, and 14 cm at 1, 10, and 27 MHz, respectively; the values are about 10 times greater for fat. Thus, although RFR at the frequencies in the OTH-B range is deeply penetrating, most of the incident power density is reflected at the surface of the body. At 100 kHz, the penetration depths of all constituents are quite large, but the reflection ratio is essentially 100%. On the other hand, at approximately 30 GHz and higher, penetration is largely confined to the outer layers of the skin.

In the literature on bioeffects of RFR, thermal energy absorption from an electromagnetic field is usually characterized by the SAR, which is defined as the rate of energy absorption per unit volume in a small volume at any locale within an entity, divided by the mean density of the constituents in that volume. SAR is expressed in units of W/kg or mW/g (1 mW/g = 1 W/kg). The numerical value of SAR in any small region within a biological entity depends on the characteristics of the incident field (power density, frequency, polarization), as well as on the properties of the entity and the location of the region. For biological entities that have complex shapes and internal distributions of constituents, spatial distributions of local SAR are difficult to determine by experiment or by calculation. Thus, the concept of "whole-body SAR," which represents the spatial average value for the body, is useful because it is a quantity that can be measured experimentally (e.g., by calorimetry) without information on the internal SAR distribution.

Many investigators have calculated or measured SAR and SAR distributions for relatively simple geometric models, including homogeneous and multilayered spheroids, ellipsoids, and cylinders that have weights and dimensions approximately representative of various species, including humans. An important result of this work is that the largest value of whole-body-averaged SAR is obtained when the longest dimension of each kind of model is parallel to the electric component of a linearly polarized plane-wave field (the "E" orientation) and when the wavelength of the incident RFR is about 2.5 times the longest dimension. The adjective "resonant" is often applied to the frequency corresponding to this wavelength. The resonant value of whole-body-averaged SAR for each model is also inversely dependent on the dimension perpendicular to the polarization direction (and propagation direction) of the field (i.e., the model has characteristics somewhat similar to those of a lossy dipole antenna in free space). Resonances would also occur for circularly polarized RFR. Such RFR can be resolved into two mutually perpendicular components, each having half the total power density. Therefore, an entity exposed to circularly polarized RFR would have lower resonant SAR values than it would have if exposed to linearly polarized RFR of the same total power density.

On the basis of prolate-spheroidal models (and linearly polarized RFR), the resonant frequency for an "average" man, approximately 5 ft 9 in. tall (1.75 m) and weighing about 154 lb (70 kg), insulated from ground, is about 70 MHz; at this frequency the mean SAR is about 0.2 W/kg for 1 mW/cm^2 incident power density, or about 1/6 of his resting metabolic rate, or about 1/21 to 1/90 of his metabolic rate when performing exercise ranging from walking to sprinting. An alternative interpretation of this mean SAR value is that exposure to 1 mW/cm^2 for, say, 1 hr would produce a mean temperature rise of about 0.2° C in the absence of any heat-removal mechanisms. At 30 MHz, the SAR is about 0.02 W/kg per mW/cm^2 for the E orientation. Therefore, exposure of the model man to the same power density for the same duration, but at 30 MHz, would produce a mean temperature rise of only about 0.02° C. However, actual temperature increases would be lower or even zero because physical heat-exchange mechanisms (conduction, convection, radiation) are always present, and for mammals (and other warm-blooded species) these mechanisms are controlled by thermoregulatory systems.

Similarly, the resonant frequency for an "average" woman (also insulated from ground), about 5 ft 3 in. tall is about 80 MHz, and her mean SAR is about the same as for the average man. The resonant frequency of a 10-year-old child is about 95 MHz; for a 5-year-old, about 110 MHz; and for a 1-year-old, about 190 MHz. The mean resonant SAR values for such children are about 0.3 W/kg for 1 mW/cm^2.

Outside the exclusion fence, the average incident power densities will be 0.1 mW/cm^2 or less. The mean SARs and temperature rises would therefore be one-tenth of those cited above. As frequency decreases from 30 MHz to 3 MHz, a further, considerable reduction in SARs occurs. Thus, the likelihood of whole-body temperature rise as a result of heating due to exposure to the fields outside the exclusion fence is negligible.

Similar data for a prolate-spheroidal model of a "medium" rat (0.2 m long and weighing 0.32 kg) indicates that the resonant frequency is approximately 650 MHz (i.e., higher than any of the values for humans), and that the resonant SAR is also larger (about 0.8 W/kg for the rat, compared with about 0.2 W/kg for man per mW/cm^2 of incident power density). Therefore, scaling of data from experimental animals to humans must consider such differences of whole-body SAR as well as frequency. To illustrate this point, the SAR of the medium rat is about 0.2 W/kg per mW/cm^2 (in the E orientation) at 2.45 GHz--a frequency that has been used in many laboratory studies of bioeffects of RFR. Coincidentally, this SAR value is about the same as that for the average man at resonance (70 MHz), but it is 10 times as great as his value at 30 MHz. Therefore, extrapolation of any bioeffects seen in rats from exposure to 1 mW/cm^2 at 2.45 GHz to humans exposed to the same power density at 30 MHz (or lower) would be highly questionable. (The human would have to be exposed to 10 mW/cm^2 to have the same SAR as the

rat.) Alternatively, to obtain the same SAR in the medium rat as that for the average man exposed to any given value of power density at 30 MHz (e.g., 1 mW/cm^2) it would be necessary to expose the rat to one-tenth of that power density (i.e., 0.1 mW/cm^2 in this numerical example) at 2.45 GHz.

If model humans were to be standing in bare feet on a wet surface or touching other electrically conductive surfaces (reflectors), their resonant frequencies would be approximately halved, yielding values close to the upper end of the OTH-B frequency range. Also, their mean SARs (at the lower resonant frequency) would be higher. However, because the values of incident power density from the OTH-B transmitter at ground level beyond the exclusion area are much lower than 0.1 mW/cm^2, no changes in body temperature would be expected.

The foregoing discussion of mean SAR is also largely applicable to FM-CW RFR, pulsed RFR, and other types of AM RFR at corresponding carrier frequencies and time-averaged incident power densities. (However, as discussed in the next section, there are several differences in interaction between CW and pulsed RFR.)

An early, significant finding for spherical models of the isolated head assumed to be exposed to plane-wave RFR was the discovery of local regions of relative maximum SAR values. The locations of such regions depend on the size of the head, the electromagnetic characteris- tics of its layers, and the wavelength of the incident field. These regions have been conveniently dubbed "hot spots," even for combinations of incident power density and exposure duration that would produce biologically insignificant temperature increases at such spots. Pertinent hot-spot data are given in the review cited in Section 4.14.1.1.2.

Results of theoretical analyses of SARs have been verified experimentally. Physical models of simple geometry or in human- or animal-figurine shape have been constructed from synthetic biological materials that have approximately the same electromagnetic characteristics as their corresponding biological constituents; the models were then exposed to sufficient power densities to obtain readily measurable temperature increases, which were measured immediately after irradiation.

Among the qualitative results of general interest obtained with human figurines are that, at frequencies near resonance, the local fields can be much higher for certain regions such as the neck and groin than for other body locations, and that field distributions for nonprimates are quite different from those for primates, a point that needs to be given proper consideration when extrapolating experimental bioeffects findings on laboratory animal species to humans or in comparing experimental results on one laboratory species with those on another species.

4.14.2.2 Quantum Interactions and Nonthermal Effects

For short-range quantum interactions (as defined above) of CW RFR, the discrete frequencies are in the infrared range from about 19,000 to 2,400,000 GHz, and the lower end of this range is about 630,000 times higher than a quantum of RFR at 30 MHz. Conversely, the quantum energy of 30-MHz radiation is too low (by a factor of more than a million) for such interactions. Therefore, the existence of nonthermal biological effects of CW RFR ascribable to such short-range molecular interaction mechanisms is extremely doubtful.

It has been logically postulated that cooperative or long-range quantum processes in biological entities (or the functions resulting therefrom) could be altered by exposure of the entity to external fields of magnitudes that do not produce heat as the primary or initial product. Much research has been conducted with models of cellular membranes. In general, the results indicate that cooperative processes have activation energies or exhibit resonant frequencies that can be much lower than those for short-range interactions.

The mean thermal energy corresponding to the physiological temperature 98.6° F (37° C) is about 0.027 eV, with a classical spectral distribution around a maximum at 6,500 GHz and encompassing the frequency range for cooperative processes. Therefore, as a counter-argument to the manifestation of such nonthermal effects, a question has been raised of whether these effects would be distinguishable from those that are spontaneously induced thermally _in vivo_. Alternatively, separation of such RFR interactions from those thermally induced may require that the rates of occurrence of the former exceed the rates for the latter. This requirement implies that for manifestation of such effects of RFR, the intensity of the incident field must exceed minimum values or thresholds related to the specific processes.

Because predictions from various theoretical models and related considerations conflict to a significant extent, the issue of whether weak external fields at frequencies well below the infrared range (i.e., RFR) can alter biological processes is not yet resolved. However, increases and decreases of calcium-ion binding to cell membranes due to weak external RFR, a phenomenon called "calcium efflux," have been ascribed to alterations of cooperative processes by such fields. This phenomenon is discussed in Section 4.14.3.5.2.

4.14.2.3 Interactions of RFR Pulses

Although the RFR from the OTH-B radar is not pulsed, the interactions of high pulse-power-density RFR at low average power densities are discussed here because such interactions are often cited as being "nonthermal" effects. The interactions of individual RFR pulses with an entity (biological or nonbiological) are analogous to those of mechanical impulses; an "impulse" is defined as the sudden application of a force

to an entity for a brief time, resulting in an abrupt increase in momentum. The total energy imparted to the entity depends on the magnitude of the force and the duration of its application. The interaction can be characterized as nonthermal or thermal, depending on the properties of the entity that determine the disposition of the energy. The impact of a piano hammer on a string, which excites the string into vibration at its discrete resonant frequencies (the fundamental frequency and integer-multiples thereof or harmonics) is an example of an essentially nonthermal interaction as defined previously; most of the energy is transformed into sound, which is converted into heat elsewhere.

A sudden blow to an entity such as a block of material having a set of resonant frequencies that are not necessarily harmonically related to one another will excite many of these frequencies; this illustrates the principle that an impulse contains a broad spectrum of frequencies. The results of an impact on a church bell can be characterized as nonthermal for the same reason as that given for the piano string. By contrast, the effects of a blow to a block of lead or asphalt are essentially thermal; even though some sound is produced, most of the energy is converted into heat on the surface of impact.

The temperature increase of any given region within a biological entity due to the arrival of a single RFR pulse and the imparting of its energy to the entity would be small because of the relatively large thermal time constants of biological materials. However, if the region contains a boundary between layers of widely different dielectric properties, the temperature gradient (rate of change of temperature with distance) can be large at such a boundary even though the mean temperature increase in the region is small.

One single-pulse effect known to occur in humans is the phenomenon of "microwave hearing" discussed in Section 4.14.3.5.1 or the perception of single or repetitive short pulses of RFR as apparently audible clicks. The interaction mechanisms involved are not yet completely understood. However, most of the experimental results tend to support the theory that pulse perception occurs because of transduction of the electromagnetic energy into sound pressure waves in the head at a boundary between layers having widely different dielectric properties (e.g., at the boundary between the skull and the skin or the cerebrospinal fluid). The energy in a pulse arriving at such a boundary is converted into an abrupt increase in momentum that is locally thermalized, producing a negligible volumetric temperature increase but a large temperature gradient across the boundary. Under such conditions, rapid local differential expansion would occur and create a pressure (sound) wave that is detected by the auditory apparatus. This effect is often characterized as nonthermal because the power density averaged over two or more pulses can be minuscule. Specifically, the time-averaged power density for two successive pulses is inversely proportional to the time interval between the arrival of the pulses at the perceiver, and this

interval can be indefinitely long without affecting the perception of each pulse. Therefore, the time-averaged power density has no relevance to perception. Irrespective of how the RFR-hearing phenomenon is characterized, the significant point is that the preponderance of experimental evidence indicates that the pulses are converted into actual sound waves in the tissues of the head, rather than perceived by direct RFR stimulation of the auditory nerves or the brain.

Pulsed RFR has been reported to produce other effects, such as alterations of the blood-brain barrier and behavioral changes. However, neither the auditory effect discussed above nor these other reported effects are likely to be of concern with regard to the OTH-B radar because its RFR is not pulsed.

4.14.2.4 Effects of Amplitude Modulation Per Se

Insofar as average power density is concerned, the effects of AM RFR at any given carrier frequency and power density are essentially the same as those of CW or FM-CW RFR at the same carrier frequency and power density. In addition, biological effects have been ascribed to amplitude modulation per se, notably the previously mentioned calcium-efflux phenomenon, which was reported for 50-MHz, 147-MHz, and 450-MHz RFR modulated at sub-ELF-band frequencies, and also at some sub-ELF frequencies, but not for unmodulated RFR at these carrier frequencies. However, the calcium-efflux phenomenon is not of concern for OTH-B because the RFR therefrom is FM-CW. Moreover, there is no evidence that frequency modulation causes any biological effects ascribable specifically to the modulation.

4.14.3 Present State of Knowledge Regarding Biological Effects of RFR

All evidence of the biological effects of RFR comes from observations of the results of exposure of humans, animals, or other biological specimens, such as insects, isolated organs, cell cultures, or bacteria. Theory, hypotheses, and speculation may guide experiments and help to explain observations, but in the end they are not, per se, evidence of effects. In this section, therefore, only those papers from the scientific literature that are concerned with actual exposure of biological entities are considered. The reader interested in full details of the papers is referred to the appropriate sections of the review (and critique) cited in Section 4.14.1.1.2.

4.14.3.1 Epidemiology

Epidemiology, as used in this context, refers to studies of whether one or more health-related conditions can be associated statistically with purported or actual exposure of humans to RFR (in contrast with assessments based on extrapolation from data on animals to humans). Epidemiologic results tend to be based on imprecise estimates of exposure characteristics (frequency, power density, and duration). The extent to which the control group matches the exposed group is

frequently open to question. Because matching of all relevant factors except exposure is the basis for concluding that any observed differences between groups are related to the RFR exposure, selection of an appropriate control group is critical. Despite these limitations, such studies provide almost the only information available on possible effects of actual RFR exposure in humans.

A group of reports was selected for review from the literature in the United States, Poland, Czechoslovakia, Sweden, and the USSR. These reports provide a representative sample of the kinds of information currently available and comprise studies on many thousands of humans who had been exposed to RFR over periods ranging up to several decades. Endpoints examined included mortality (was lifespan shortened?); cancer induction; birth defects, including mongolism; heart disease; general health tests such as electrocardiograms, standard blood tests, urinalyses, liver function tests, and ophthalmologic, neurologic, gynecologic, psychiatric, and psychological examinations; and (in the Soviet Union) examination for functional changes in the central nervous system described as "vegetative dysfunction accompanied by neurasthenic symptoms." (Such symptomatology is generally not in the lexicon of medicine practiced in the West.) Several epidemiologic studies were also conducted specifically to seek eye defects in persons believed to have been exposed to RFR at military and nonmilitary establishments.

In general summary, none of the U.S., Polish, and Czechoslovakian epidemiologic studies offers clear evidence of detrimental effects associated with exposure of the general population to RFR. However, the Soviet findings, which are consistent with the voluminous Soviet literature from the 1960s, suggest that occupational exposure to RFR at average power densities less than 1 mW/cm^2 does result in various symptoms, particularly those associated with disorders of the central nervous system (CNS). Because the USSR symptomatology has not been reported in Western studies and because of the marked differences between Soviet and Western publications in the procedures used for reporting data, prediction of possible RFR hazards based on the USSR epidemiologic studies would require acceptance of these Soviet findings at face value. Taking all of the epidemiologic studies together, we conclude that the results do not provide evidence that the RFR from the OTH-B radar will be hazardous to the population outside the exclusion fence.

4.14.3.2 Mutagenesis and Cancer Induction

One frequently expressed concern about RFR is that it may cause mutations. Mutagenesis and cancer induction are considered to be related, and indeed many chemicals are screened for potential cancer-causing properties by using bacterial mutation tests. Several studies for mutagenic effects of RFR have been carried out on bacteria, yeast, and fruit flies (standard test systems for mutagenesis). These studies failed to demonstrate a mutagenic effect. No mutations were found that were attributable to RFR exposure.

Other papers described a standard test for mutagenesis called the dominant lethal assay (mutations that result in the death of the embryo) using mice and rats. Marginally positive results for mice were, on reexamination, found to have been attributable most likely to uncontrolled factors rather than to RFR exposure. The study with rats failed to find evidence of mutagenic effects.

Studies on the effects of RFR exposure on the structure of chromosomes in cells of plants, animals, and humans did not reveal aberrations at power densities below 20 mW/cm^2.

When scrutinized critically, all of the studies on mutagenic and cytogenetic effects of RFR exposure reviewed indicate that the effects found probably are related to heating. Power density levels outside the exclusion fence of the OTH-B transmitter are incapable of producing significant heating. There is no evidence that such low power densities are likely to cause mutagenic effects. In addition, a report claiming that RFR exposure has increased the incidence of cancer does not withstand critical review. It does not provide evidence that exposure to RFR is likely to cause cancer. Other studies have failed to find an effect of RFR exposure on general health of the exposed animals or on the occurrence of cancer.

4.14.3.3 Studies on Teratogenesis and Developmental Abnormalities

Teratogenesis in humans is the production of malformed infants by processes affecting their development in the womb. The term, "developmental abnormalities," as used here refers to processes affecting the development of infants after birth. Teratogenic and developmental abnormalities occur naturally at a low rate in most animal species, and relatively little is known about their cause. In a few cases, however, specific agents have been shown to cause significant teratogenic effects, and hence the possibility of these effects from RFR is an appropriate matter of public concern.

Teratogenic studies with RFR have used a variety of animal models. One set of studies was performed on pupae of a beetle commonly used in scientific experiments. Several reports from different laboratories stated that relatively low levels of RFR would produce developmental abnormalities in the pupae. It later was learned that such abnormalities depended strongly on such factors as the source of the larvae and their diet before they entered the pupal stage. The amount of RFR absorbed was also, as a consequence of the RFR exposure system used, quite high.

Tests for effects on Japanese-quail eggs failed to show significant teratologic or developmental abnormalities resulting from RFR exposure.

RFR has been reported to cause various teratogenic effects in a number of studies using mice. Analysis of the dose-response data indicates an apparent threshold for such effects. At doses less than about 3 cal/g or at power densities less than about 1 mW/cm^2 there is no evidence that RFR is teratogenic. In rats, no significant differences between RFR-exposed and control groups were found in any of the parameters commonly looked for in such studies, even at power densities capable of heating the pregnant females to temperatures over 104° F.

In a study designed primarily to seek possible effects of chronic RFR exposure of pregnant squirrel monkeys on mother-infant behavior, no differences were found between RFR-exposed and sham-exposed mothers in the number of live births or the growth rates of the offspring. There was an unexpected finding of infant deaths in the small group (5 animals) with the highest RFR power exposure. When the study was repeated with a sufficient number of animals for adequate statistical treatment, the RFR-induced offspring mortality finding was not confirmed.

In summary, the studies showing demonstrable teratogenic effects following exposure to RFR have involved power density levels that are capable of producing a significant heat load in the animals. In general, the results indicate that a threshold of heat induction or temperature increase must be exceeded before teratogenic effects are produced. Because the normal human metabolic rate is of the order of 1 to 2 W/kg, the average power densities outside the exclusion fence of the CRS transmit site will not have any significant effect on body temperature that will cause teratogenic effects in humans.

4.14.3.4 Ocular Effects

The fear that RFR can cause cataracts is a recurring theme in newspapers and other popular media. Indeed, given the many investigations with animals by various researchers, it is undoubtedly true that if a person's eyes were exposed to intensities high enough to elevate the temperature of the lens of the eye by about 5° C (9° F) or more, the lens would quickly suffer damage. The lens is the region of the eye most vulnerable to RFR because other regions have more effective means of heat removal, such as greater blood circulation, evidenced by much smaller temperature elevations in these regions than in the lens at the same incident power density. Therefore, the basic concern regarding ocular effects is centered on whether exposure to much lower intensities (i.e., to power-density levels that would produce much smaller lens temperature elevations) for long periods, either continuously or intermittently, can cause eye damage. Implicit to these concerns is whether the effects (if any) of long-term, low-level exposure in the eye are cumulative.

4.14.3.4.1 Humans

Some cases of ocular damage in humans ascribed to occupational exposure to RFR were reported during the 25 years after World War II. Although the exposure histories of these individuals could not be ascertained with any degree of certitude, it is likely that their actual or incipient vision impairment resulted from exposure to average power densities substantially greater than the threshold found in animal studies (about 150 mW/cm^2).

Epidemiologic studies have been conducted to determine whether prolonged exposure to RFR is cataractogenic. These studies are mentioned in Section 4.14.3.1. No reliable reports of eye defects associated with RFR exposure were found.

4.14.3.4.2 Animals

During the past 30 years, various investigations have been conducted on the effects of RFR exposure on the eyes of live experimental animals. Many of the results indicate that intraocular temperature increases of about 5° C or more are necessary for eye damage. Also, no lens opacifications were caused by RFR exposure when the eye was cooled during exposure, indicating intraocular temperature rise was a major factor in eye damage.

Many of the results of RFR exposure indicate the existence of a threshold average power density of about 150 mW/cm^2 to produce cataracts in experimental animals. The existence of a cataractogenic threshold implies that single or multiple exposure for indefinitely long durations at average power densities well below the threshold would not cause eye damage to humans or any other species.

In summary, on the basis of experimental results with animals that indicate the existence of a threshold power density of 150 mW/cm^2 and the finding of no statistically significant differences between exposed and control groups of humans from epidemiologic studies, there is no evidence that prolonged exposure of humans to the RFR from the OTH-B transmitter at the power densities existing outside the exclusion area is likely to cause eye damage.

4.14.3.5 Studies of the Nervous System

Several types of studies have been conducted on effects of RFR on the nervous system of animals. These studies are considered particularly important in the USSR, where RFR is believed to stimulate the nervous system directly and thereby cause a variety of physiological effects. Scientists in the United States tend to doubt that RFR interacts directly with the nervous system except, possibly, under special circumstances (discussed in the next section), and they consider most effects of RFR on the nervous system to be indirect results of other physiological interactions.

4.14.3.5.1 RFR Hearing Effect

Humans in the vicinity of some types of pulsed radar systems have perceived individual pulses of RFR as audible clicks (without the use of any electronic receptors). This phenomenon has attracted much interest--especially in the United States--because it has often been cited as evidence that nonthermal effects can occur and because an initial hypothesis was that one of the possible mechanisms for perception is direct stimulation of the CNS by RFR. Various theoretical and experimental studies, the latter both with human volunteers and with laboratory animals, have been conducted to determine the conditions under which pulsed RFR is audible and to investigate the interaction mechanisms involved. Many of the results support the hypothesis that a pulse of RFR having the requisite pulse power density and duration can produce a transient thermal gradient large enough to generate an elastic shock wave at some boundary between regions of dissimilar dielectric properties in the head, and that this shock wave is transmitted to the middle ear, where it is perceived as a click. Persons with impaired hearing are unable to hear such clicks, and experimental animals in which the cochlea (the inner ear) has been destroyed do not exhibit brainstem-evoked responses. However, even though the existence of the RFR-hearing effect is well established, it is of no concern with regard to the OTH-B radar because its RFR is not pulsed, but rather is FM-CW.

4.14.3.5.2 Calcium Efflux

Exposure of samples of brain tissue from newly hatched (neonatal) chicks to RFR amplitude-modulated at low frequency has been reported to increase the rate of exchange of calcium ions between the tissue and the fluid bathing it. This effect has been demonstrated by two groups of investigators. Most of the studies were carried out on isolated tissues maintained in physiological solutions. Similar alterations in calcium ion exchange were reported for exposed brains of paralyzed live cats irradiated at 3 mW/cm^2 with 450-MHz RFR sinusoidally amplitude modulated at 16 Hz.

Interpreting these results with regard to human health and safety is difficult. First, the phenomenon is subtle. Large numbers of samples have to be processed to show a statistically significant effect. Second, the observations are highly variable and difficult to reproduce. Third, the circumstances of the experimental methodology are such that the observations of changes of calcium exchange appear to apply to the surface region of the brain rather than to the brain as a whole. Finally, the phenomenon depends on the amplitude modulation of the RFR in a narrow frequency band around 16 Hz and only occurs for narrow ranges of average power densities (windows) between 0.1 and 3.6 mW/cm^2. The effect is scientifically interesting, in that it represents a rare instance where RFR may be producing a biological effect by processes other than thermal mechanisms. However, the phenomenon is not directly relevant to OTH-B because the RFR from its transmitter is not amplitude modulated.

4.14.3.5.3 Blood-Brain Barrier Effects

In most organs and tissues of the body, molecules in the blood can freely diffuse into the tissue around the capillaries. However, presumably to protect the brain from invasion by various blood-borne microorganisms and toxic substances, large molecules such as proteins or polypeptides exhibit little or no movement from the blood into the surrounding brain tissue in most regions of the brain. The exact manner by which the movement is prevented is still conjectural, but the process is referred to as the "blood-brain barrier" (BBB). The BBB can be "opened" by certain agents (e.g., ionizing radiation, heat) or chemical substances (e.g., dimethyl sulfoxide). Studies have been conducted to examine whether RFR can alter the BBB permeability of animals to various large molecules.

Early studies suggested that RFR at relatively low levels could affect BBB permeability in the rat. Later studies were unable to confirm these findings, and indeed found that the results were likely to have been artifacts introduce by the experimental techniques that had been employed. At higher power densities sufficient to cause heating (above several mW/cm^2), RFR does appear to cause alteration in BBB permeability to various substances.

On the basis of current evidence, it is quite unlikely that exposure of people to the levels of RFR existing at ground level outside the exclusion fence of the OTH-B transmit site would have any effect on the permeability of the BBB because the levels of RFR are insufficient to cause heating of the brain.

4.14.3.5.4 Histopathology and Histochemistry of the Central Nervous System

Histopathology is defined as the study of diseased or damaged tissues, and histochemistry as the study of the chemical composition of various tissues. Studies of histopathological effects of RFR on the brain have been conducted in both the United States and the USSR. Studies in the USSR have covered a wide range of frequencies, but the reporting of dosimetry and methods was in many instances inadequate to enable a critical evaluation of the validity of the experiments or of the findings. In the United States, studies of histopathological effects of RFR on the brain have been performed on hamsters and rats, where effects have been seen, and on squirrel monkeys, where effects have not been seen. The levels of RFR to cause the effects in rodents were 10 mW/cm^2 and higher, which, because of a resonance phenomenon between the skull of such a small animal and the RFR frequency used, could have resulted in high RFR absorption levels in the brain. The observed effects seem likely, therefore, to have resulted from thermal processes.

Other studies have examined effects of RFR on brain neurochemistry. One showed no effects on specific neurotransmitters of mouse brain; the other showed small (5% to 10%) changes in tissue respiration of subcellular components. The significance of this latter finding is unclear, but it is not likely to be indicative of a hazard because of the wide range of tissue respiration values possible in various environments and activities.

In summary, RFR can cause observable histopathological changes in the CNS of animals but it appears that these changes are thermal. Under special conditions of frequency and skull size, a focusing effect can be obtained in small rodents, causing local SARs tens of times higher than would normally be expected from whole-body SAR measurements. Such conditions do not occur for the adult human skull. One study has reported small changes in brain tissue respiratory chain function at a power density of 5 mW/cm^2. It is unlikely that such effects would be detectable at the power densities at ground level outside the the OTH-B transmitter exclusion fence. These studies provide no evidence that exposure to such power densities are likely to be hazardous.

4.14.3.5.5 Electroencephalogram (EEG) Studies

Studies have been conducted to ascertain the effects of RFR on the EEG or other related electrophysiological properties of the CNS. For EEG measurements made after RFR exposure, the time consumed in placing and attaching the electrodes and the variability of placement introduce problems of interpretation. Additionally, if the effects are transient, they may stop when exposure ceases. For studies attempting to measure EEG changes during application of the RFR, the electrodes and leads used to pick up EEG signals also pick up electrical signals directly from the fields, causing artifacts that render the recordings difficult to interpret. In addition, indwelling or chronically attached electrodes will perturb the electric fields in their vicinity, and produce great enhancement of energy absorption, thereby creating still another artifact in the biological data. To meet these problems, specially designed indwelling electrodes of high-resistivity materials that do not cause field perturbation have been constructed and used in a few of the more recent studies.

Experiments in which such specially constructed electrodes were used, or in which electrodes were applied after exposure, show no evidence of statistically significant differences in EEGs or in evoked responses between control and RFR-exposed animals. There is therefore no evidence that ground-level RFR from the OTH-B transmitter is likely to cause any effects on the EEG or evoked potentials of populations outside the exclusion fence. One study does indicate the possibility that persons with indwelling metallic electrodes in the brain or prosthetic metallic plates on the skull may have effects induced in their EEGs or evoked potentials in the vicinity of the exclusion fence, where the highest average power density is about 0.1 mW/cm^2, but only if they are there for extended periods (several months).

4.14.3.6 Effects on Behavior

Many experimental studies have been conducted on the effects of RFR on animal behavior. The results of such studies are considered particularly important in the USSR, where they are often considered to be evidence for direct effects of RFR on the CNS. Scientists in the United States do not always agree that behavioral effects necessarily imply direct effects on the CNS. However, behavioral effects are very sensitive indicators of biological function and hence receive appropriate attention in both Eastern European and Western countries. The papers described in the review were selected as representative of the types of behavioral studies that have been conducted. These include studies of effects on reflex activity, studies of RFR-perception, evaluations of effects of RFR on learning and on performance of trained tasks, studies of interactive effects of RFR and drugs on behavior, and investigations of behavioral thermoregulation. Studies have been conducted on mice, rats, rabbits, squirrel monkeys, rhesus monkeys, and humans.

Again, conflicts occur between Soviet claims of effects at low (equal to or less than 0.5 mW/cm^2) power densities for long-term exposures and the absence of similar effects in the same power density range in the studies by U.S. researchers. The validity of the Soviet claims is difficult to assess because of lack of reported detail of the experiments. It is certainly likely that such effects could be seen if indwelling electrodes were used for the animals involved in the Soviet studies, but whether such was the case is unknown.

In summary, and with the above qualification, RFR is capable of producing alterations in a wide variety of behaviors of various species of animals. Except for pulsed RFR, the average power densities required to modify behavior are almost all at levels of approximately 5 mW/cm^2 and above, and most appear to be in the thermal range. Perception of pulsed RFR is a peak power phenomenon, not an average power one (as discussed in Section 4.14.3.5.1), and can thereby modify behavior. However, it is not relevant to the OTH-B radar, which is an FM-CW rather than a pulsed system.

It is difficult to relate most of the behavioral studies in animals to humans. All behavioral studies are directly relevant to the nature of the species being studied, and the conclusions of a given study do not readily transfer to other species. Because of the power densities needed to cause reported effects, however, these studies provide no evidence that exposure to RFR at the levels outside the CRS exclusion fence is likely to have adverse effects on human behavior.

4.14.3.7 Endocrinological Effects

Exposure of animals to RFR has produced somewhat inconsistent effects on the hormone-secreting (endocrine) system of mammals. In general, the effects produced appear to be related either to stress induced in the animals by the heat load associated with the RFR or to

perception of the RFR and, possibly, other experimental circumstances. Some effects also appear to be secondary to alteration of the circadian rhythm by heat stress resulting from RFR exposure, but these effects are subtle and of dubious relevance to the low levels of the OTH-B system. There do not appear to be any effects clearly demonstrated to be associated with nonthermogenic stimulation of the endocrine system or the associated parts of the CNS.

Although some of the effects of RFR exposure on the endocrine system (e.g., results from heating of the testes by RFR) appear to be relatively straightforward and predictable from physiological considerations, other, more subtle effects require further study--notably those related to the interactions among the pituitary, adrenal, thyroid, and hypothalamus glands and/or their secretions. There is currently no evidence that such subtle effects are hazardous. Part of the problem in interpreting results appears to arise from uncertainties regarding stress mechanisms and accommodations thereto. Animals that are placed in novel situations for an experiment are much more prone to exhibit stress responses than animals that have been adapted to the situation. However, the variations in adaptation among animals may be large in a given situation or among experimental situations in different laboratories.

In conclusion, because the reported effects of RFR on the endocrine systems of animals are largely ascribable to increased thermal burdens, stresses engendered by the experimental situation, or both, there is no evidence that such effects would occur in humans exposed to the RFR from the OTH-B radar outside the exclusion fence.

4.14.3.8 Immunological Effects

Studies to date indicate that RFR has quite definite effects on the immune system of mammals. Most of the reported effects were detected after exposure at power density levels of about 10 mW/cm^2 and higher; a few have been detected following exposure to power densities as low as about 0.5 mW/cm^2; and in some cases, effects obtainable with the higher power-density range were not found at lower power densities, indicating the possibility of a threshold power density for the effect. In most studies, the mechanisms for the effects seen were not investigated, and the various reports are somewhat inconsistent. The situation is complicated by the complexity of the immune system and the variety of test procedures used.

Some studies suggest suppression of immune system function, some suggest stimulation, and others, both effects. Furthermore, results from various laboratories obtained under apparently comparable conditions are sometimes contradictory and indicate the probable presence of uncontrolled factors or subtle differences in the experimental protocols.

Given current findings, it appears that RFR-induced effects on the immune system of intact animals depend to varying degrees on the ages of the experimental subjects, the frequency and average power density of

the RFR (or the whole-body SAR resulting therefrom), the exposure duration and perhaps the time of day when the exposures are given, the kind of exposure system used (which affects the internal SAR distributions within the animals), and the kind of endpoint analyses undertaken and when they are performed relative to the completion of exposures.

Reported effects on the immune systems of intact animals from chronic exposure to RFR at average power densities below 1 mW/cm^2 are unlikely to be linked simply to temperature increases, but such results have not yet been repeated elsewhere. In most other similar investigations, the exposures were at average power densities exceeding 1 mW/cm^2. The existing evidence indicates that some of the immune-system effects are probably mediated through the effect of RFR on the endocrine system, involving the general syndrome of adaptation to stress. The mechanisms and significance of such effects are not yet understood, nor have individual findings been independently verified. There is no evidence that the RFR effects on the immune systems of animals reported would occur in humans chronically exposed to the levels of RFR from the OTH-B radar outside the exclusion fence or that such effects would be hazardous to human health.

4.14.3.9 Biochemical and Physiological Effects

The literature on biochemical and physiological effects associated with RFR is extensive. Many of the reported effects are associated with other events (e.g., changes in hormonal levels or stress adaptation), some are questionable for various reasons, and others do not have a clear medical significance.

The thermal basis for most of the reported physiological and biochemical effects of exposure of intact animals to RFR is evident. Most significant with respect to possible hazards of human exposure to RFR are the investigations with nonhuman primates because their anatomies and physiological characteristics are closer to those of humans than are those of other experimental animals. The results with rhesus monkeys showed that exposure to RFR at frequencies in the HF range at average power densities of the order of 100 mW/cm^2 were well within the thermoregulatory capabilities of this species. Also noteworthy were the negative findings of the blood-chemistry assays performed on rhesus monkeys 1 to 2 years after exposures to such high power densities and observations that the thermoregulatory system of the squirrel monkey is quite effective in compensating for RFR exposure.

The investigations involving exposure of intact, smaller species of mammals to RFR have yielded a variety of positive and negative results. Some of the positive findings are also clearly due to the additional thermal burden imposed by the RFR. Other results, such as those on decreased food intake and lower blood glucose levels in rats, indicate the existence of an SAR threshold of about 1 W/kg or higher for such effects.

One physiological aspect of concern is whether exposure of humans to RFR can affect their heart functions. In early work on this subject with excised turtle, frog, or rat hearts, various investigators reported RFR-induced bradycardia (decrease in pulse rate), tachycardia (increase in pulse rate), or both (depending on average power densities, with bradycardia for the lower range of power densities used). The lowest SAR at which bradycardia was observed in the isolated turtle heart was 1.5 W/kg. More recently, no RFR-induced changes were found in beat rate or contractile force in isolated atria of rat hearts exposed to 2.45-GHz CW RFR at 2 or 10 W/kg.

SAR-dependent changes in heart beat rate in intact animals were also reported. The results indicate the existence of a threshold between 4.5 and 6.5 W/kg, many orders of magnitude higher than could occur outside the exclusion fence of the OTH-B transmitter.

Overall, the general conclusion of the review is that the occurrence of physiological or biochemical effects from exposure to the RFR from the OTH-B transmitter at the levels outside the exclusion fence is extremely improbable.

4.14.3.10 Effects on Small Animals within the Exclusion Fence

As described in Section 4.14.2.1, thermal energy absorbed from an electromagnetic field is usually characterized by the specific absorption rate (SAR). This is defined as the rate of energy absorption per unit volume in a small volume at any locale within an entity, divided by the mean density of the constituents in that volume. The usual units of SAR are W/kg. Whole-body SAR, representing the spatial average for the body, is the measure most used in practice because it can be measured experimentally without requiring informaton on the internal SAR distribution.

Given the size and orientation of an animal with respect to an incident RF field, it is possible to calculate the whole-body SAR. From Table B-2, the highest near-field power density occurs for band F: 258 mW/cm^2. The field for this band is vertically polarized. A human in the field is therefore parallel to the E-field, a condition resulting in the greatest absorption of RFR. Quadruped animals are perpendicular to the E-field and absorb somewhat less RFR. Absorption also depends on the size of the animal relative to the wavelength of the incident field.

Calculated whole-body SARs are given in Table 4-7 for man and for representative small animals that might live witin the exclusion fence. The 1982 ANSI C95.1 Radiation Protection Guide for humans is based on permissible unrestricted exposure of the body resulting in an SAR of 0.4 W/kg, spatially and temporally averaged over the entire body. From the table, the human exceeds the ANSI Guide by a factor of 13. However, the smaller animals have much lower SARs.

Table 4-7

MAXIMUM WHOLE-BODY SARS INSIDE THE EXCLUSION FENCE*

Entity	Whole-Body SAR (W/kg)
Human (154 lb)	5.2
Beagle-sized dog (30 lb)	0.26
Rabbit (2.2 lb)	0.052
Large mouse (1 oz)	0.026

*Incident field 28 MHz, vertical polarization, 258 mW/cm^2.

Source: C. H. Durney et al., (1978).

The literature on RFR biological effects indicates that whole-body SARs associated with thresholds of potentially harmful effects occur in the range between 4 and 8 W/kg. Therefore, no effects on small animals living inside the exclusion fence from the relatively high levels of RFR would be discernible, even though such levels would be potentially harmful to humans.

4.14.4 Misconceptions

Several misconceptions regarding RFR bioeffects continue to be expressed in popular accounts outside peer-reviewed scientific publications on the subject. Those accounts tend to be sources of some confusion for the nonspecialist. Representative examples follow.

The distinction between RFR and ionizing radiation is often not made; consequently, the known hazards of ionizing radiation are linked--by implication--with exposure to RFR. In essence, ionizing radiation (which includes ultraviolet light, X-rays, and the emissions from radioactive materials) has sufficient quantum energy (see Section 4.14.2.1) to expel an electron from a molecule, leaving the molecule positively charged and thereby strongly affecting its interactions with neighboring molecules. Ionization can alter the functions of biological molecules fundamentally and often irreversibly.

By contrast, the quantum energies of RFR are so much smaller that their primary effect is to agitate molecules rather than to ionize them. (The possibility of long-range quantum interactions, discussed in Section 4.14.2.1.3, is not excluded; however, evidence of their occurrence in live animals is sparse as yet, and there is no evidence that

such effects would be harmful if they did occur.) Also, RFR-induced agitation ceases as soon as exposure to RFR is halted. At low RFR intensities, the heat that such agitation represents is well accommodated by the normal thermoregulatory capabilities of the biological entity exposed, and therefore such effects are generally reversible. At high RFR intensities, the thermoregulatory capabilities may be inadequate to compensate for such effects, and exposure at such intensities may lead to thermal distress or even irreversible thermal damage. In short, a single quantum of ionizing radiation that is absorbed by a molecule alters the properties of that molecule, and exposure to such radiation may thereby profoundly affect the function of the biological constituent involved, whereas the concurrent absorption of many quanta of RFR is necessary to cause biologically significant effects.

Even if an effect is produced by RFR, that effect may not necessarily be deleterious to the entity involved. As an example of a nonhazardous biological effect, the absorption of visible light (a form of electromagnetic radiation having quantum energies above those of RFR but below those of the ionizing radiations mentioned previously) in the eyes is necessary for vision. Light is also absorbed by the skin and at normal levels is converted into harmless heat. One of the reasons that the levels of allowable exposure of humans to RFR are generally lower in Eastern European countries than they are in the West is the philosophically based assumption that even small RFR-induced effects are potentially harmful--a view not generally shared in Western countries.

Concerned people often ask whether guarantees can be offered that chronic exposure to low levels of an agent such as RFR will have no deleterious effects many years in the future. It is scientifically impossible to obtain data on which a guarantee of absolute safety can be based. An infinitely large number of experiments to test all hypothetically hazardous situations would have to be performed. However, the large body of experimental data on RFR bioeffects indicates that, unlike the ingestion of certain substances in small quantities that can accumulate into a potentially harmful dose, RFR energy continually absorbed at low incident power densities (dose rates) is readily dissipated and does not accumulate in the body toward the equivalent of RFR energy absorbed at high incident power densities. This is one of the basic reasons for the existence of threshold power densities for the various RFR bioeffects.

4.14.5 Unresolved Issues

The potential biological effects of RFR have been assessed from existing studies at frequencies up to 300 GHz. Based on the studies evaluated, with recognition that the negative findings reported in some studies may have been obtained because the experiments had been poorly conducted, no reliable evidence exists to indicate that chronic exposure to RFR at incident average power densities below 1 mW/cm^2 or at SARs below 0.4 W/kg is likely to be hazardous to human health. However, certain gaps remain in our knowledge of the biological effects of RFR.

(1) Epidemiologic Studies. Epidemiologic studies of effects of exposure of humans to RFR, in which the actual frequencies, levels, and durations of exposure are accurately known and quantified, are lacking. Existing epidemiologic studies, while extensive and reasonably well done, have inherent defects, such as unavailability of complete medical records, death certificates, or health questionnaires, or imprecise classification of the individuals with regard to RFR exposure.

(2) Extrapolation of Findings on Animals to Humans. Obviously, the most directly applicable experimental evidence relevant to possible bioeffects of exposure to the RFR from any specific system such as the OTH-B radar would be from studies in which humans were exposed to the frequencies and waveform characteristics of that kind of system for appropriate durations at the pulse and average power densities likely to be encountered. Furthermore, quantitative evaluation of a large number of biological end-points would be necessary. Such data, of course, do not exist. Instead, data are obtained from laboratory animals (mostly small rodents) used as surrogates for humans, a standard practice for investigating the effects of other agents. Because of the biological differences among species, a basic uncertainty is the degree of validity of this practice, which depends in part on the species used, the nature of the agent and its quantitative aspects, and the biological endpoints studied. In investigations of RFR bioeffects, much progress has been achieved in quantifying exposures in terms of whole-body SARs and internal SAR distributions in animal carcasses and in physical and mathematical models of various species (including humans). For example, such data can be used to determine what the whole-body SARs would be in humans at a frequency in the 5- to 28-MHz range, if, say, laboratory rats are exposed to 2.45-GHz RFR at prespecified power densities. Nevertheless, significant gaps in knowledge remain regarding internal SAR distributions in humans. Moreover, most such interspecies calculations do not endeavor to account for the roles of blood flow and other factors in determining heat flow patterns or of thermoregulatory mechanisms in mammals that maintain constant body temperatures.

(3) Thresholds and Long-Term, Low-Level Studies. Most experimental data indicating the existence of threshold power densities for various RFR bioeffects were obtained from exposures for relatively short durations. Although it is difficult to conceive of mechanisms whereby RFR exposures at well below threshold values over a long time could result in cumulative effects deleterious to health, very few investigations have involved exposure of animals to low-level RFR over a large fraction of their lifetimes.

In light of these gaps, the possibility that new information would reveal a significant hazard from chronic exposure to low levels of RFR cannot be dismissed, but is judged to be relatively low.

4.14.6 Conclusions

Epidemiologic studies performed in the United States and other countries do not provide adequate scientific evidence that environmental levels of RFR constitute a hazard to the general population.

Most U.S. experiments with animals that yielded recognizable and repeatable effects of exposure to RFR were performed at whole-body average SARs of more than about 1 W/kg. Such effects are thermal, in the sense that the RFR energy is absorbed by the organism as widely distributed heat that increases the whole-body temperature, or as internally localized heat that is biologically significant even with functioning natural heat-exchange and thermoregulatory mechanisms operating. The existence of threshold incident average power densities has been experimentally demonstrated for some effects and postulated for others. Exposure to RFR at average power densities exceeding the threshold for a specific effect for durations of a few minutes to a few hours (depending on the value) can cause irreversible tissue alterations. The heat produced by indefinitely long or chronic exposures at power densities well below the threshold is not accumulated because its rate of production is readily compensated for by heat-exchange processes or thermoregulation. Most investigations involving chronic exposures of mammals yielded either no effects or reversible, noncumulative behavioral or physiological effects for average power densities exceeding 1 mW/cm^2 and whole-body SARs of 1 W/kg. In the few cases in which irreversible adverse effects of exposure were found, such effects were absent for average power densities below 1 mW/cm^2 and whole-body SARs below 1 W/kg.

In a relatively small number of investigations, biological effects of RFR were reported at incident average power densities less than about 1 mW/cm^2. Such effects have been called "nonthermal," to distinguish them from those considered above. However, this usage of "nonthermal" is confusing and imprecise because the interaction mechanisms involved in each such effect differ considerably from those for the other effects, and clear distinctions between "thermal" and "nonthermal" based on precise scientific definitions of these terms are difficult to discern in the interactions. Among the so-called nonthermal effects of RFR that have been documented to date are the RFR auditory phenomenon and the calcium-efflux effect. However, because the OTH-B radar will emit FM-CW RFR rather than pulsed- or amplitude-modulated RFR, neither phenomenon is relevant to OTH-B operation. Moreover, no known effects have been attributed to the frequency modulation per se of FM-CW RFR.

In summary, the review of the relevant literature indicates that no reliable scientific evidence exists to suggest that chronic exposure to the RFR from the CRS outside the exclusion fence would be deleterious to the health of even the most susceptible members of the population, such as the unborn, infirm, or aged.

5 LIST OF PREPARERS

Burton B. Bryan, Metcalf & Eddy, Inc., Ph.D. (1977) in biology, 16 years' experience in biological impact analysis. Dr. Bryan prepared the sections on vegetation, wetlands, and wildlife.

John A. Chamberlain, SRI International, B.S. (1982) in meteorology, 4 years' experience in air quality impact studies and wind analysis. Mr. Chamberlain prepared the air quality impact sections.

Sue A. Cobler, Metcalf & Eddy, Inc., M.S. (1985), 2 years' experience in environmental analysis. Ms. Cobler prepared the sections on biological analysis relating to birds.

Marilyn D. Duffey, consultant to SRI International, M.S. (1971) in cybernetics systems, 15 years' experience in environmental analysis. Ms. Duffey prepared the aesthetics sections.

William A. Edson, SRI International, D.Sc. in electrical communications, 48 years' experience in communications, radar systems, and antennas. Dr. Edson prepared Appendices A and B and the description of the RFR fields in Section 4.

Stephen A. Estes-Smargiassi, Metcalf & Eddy, Inc., M.C.R.P. (1982), 6 years' experience in demographic and environmental analysis. Mr. Estes-Smargiassi was the task leader for the natural environment and infrastructure sections.

Sidney J. Everett, SRI International, Ph.D. (1978) in environmental analysis, 13 years' experience in environmental impact assessment and project management. Dr. Everett was the EIS project leader; he prepared Sections 1 and 2.

Michael L. Gregg, University of North Dakota, Ph.D. (1975) in anthropology, 16 years' experience in the prehistoric archeology of the American Midwest and Northern Plains. Dr. Gregg was the principal editor for the cultural resources sections; he prepared the prehistoric and historic cultural resources background, the cultural resources sections on South Dakota, and the overviews.

Mark R. Hollyer, SRI International, M.C.R.P. (1977), 12 years' experience in regional planning, socioeconomic analysis, and economic impact assessment. Mr. Hollyer prepared the portions of Sections 3 and 4 related to socioeconomic analysis.

Lisa A. Jeffrey, Metcalf & Eddy, M.S. (1985) in civil engineering, 2 years' experience in water resource and water quality impact analysis. Ms. Jeffrey prepared the water resources sections and assisted in the editing of the sections contributed by Metcalf & Eddy.

Mark H. Johnson, P.E., Metcalf & Eddy, Inc., B.S.C.E. (1977), 9 years' experience in infrastructure engineering. Mr. Johnson prepared the section on transportation and solid waste.

Richard D. Johnson, SRI International, Ph.D. (1961) in physical organic chemistry, 22 years' experience in chemistry, life sciences, and technology. Dr. Johnson was the assistant EIS project leader and the task leader for the biophysical environment sections.

Cynthia Kordecki, University of North Dakota, B.A. in anthropology and theology (1971), 11 years' experience in the prehistoric archeology of the American Midwest and Northern Plains. Ms. Kordecki conducted site file and literature searches for North Dakota and South Dakota, and prepared the North Dakota sections on cultural resources.

James T. Maughan, Metcalf & Eddy, Inc., Ph.D. (1986) in Environmental Science, 13 years' experience in environmental analysis and project management. Dr. Maughan was the Environmental Impact Analysis Process Manager for Metcalf & Eddy, Inc.

Scott Nagel, consultant to Metcalf & Eddy, Inc., B.A. (1971) in geology, 16 years' experience in engineering geology. Mr. Nagel prepared the portions on geology, soils, minerals, and earthquakes.

Jeannette Nishida, SRI International, M.A. candidate in anthropology. Ms. Nishida coordinated the sections on cultural resources and researched the issue of bird collisions with man-made structures.

James Peter, Metcalf & Eddy, Inc., B.S.C.D. (1982), 4 years' experience in civil and geotechnical engineering. Mr. Peter assisted in the preparation of the sections on transportation, solid waste, and water and wastewater utilities.

Peter Polson, consultant to SRI International, Ph.D. (1972) in physiology, 12 years' experience in studies of the bioeffects of electromagnetic fields. Dr. Polson prepared the sections on RFR bioeffects.

Richard A. Shepherd, SRI International, M.S.E.E. (1969), 26 years' experience in telecommunication systems and electromagnetic compatibility analysis and evaluation. Mr. Shepherd prepared Appendix C and the corresponding text in Sections 3 and 4.

Fern E. Swenson, University of North Dakota, B.A. in anthropology and American studies (1976), 10 years' experience in the prehistoric archeology of the American Midwest, Southern Plains, and Northern Plains. Ms. Swenson conducted site file and literature searches for Minnesota and wrote the Minnesota sections on cultural resources.

6 REFERENCES

ANSI (American National Standards Institute) (1982). C95.1-1982, "Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 300kHz to 100 GHz," published by the Institute of Electrical and Electronics Engineers, New York.

API (American Petroleum Institute) (1983). Environmental Affairs Department. "Guide to Groundwater Standards of the United States," API Publication 4366.

Artz, Joe Alan (1984). A Cultural Resource Reconnaissance of Two Proposed Bank Unloading Areas, East Grand Forks, Polk County, Minnesota, Department of Anthropology and Archaeology, University of North Dakota, Grand Forks. Submitted to the St. Paul District, Corps of Engineers, St. Paul, Minnesota.

Ashe, Dean (1986). Area Fisheries Manager, Minnesota Department of Natural Resources, personal communication

ASSHTO (American Society of State Highway and Transportation Officials) (1977). "Standard Specifications for Highway Bridges," 12th Edition, Washington, D.C.

Atwood, W.W. (1940). The Physiographic Provinces of North America, Ginn and Co., Boston.

Avery, M.L., P.F. Springer and F.J. Cassel (1975). "Progress Report on Bird Losses at the Omega Tower, Southeastern North Dakota," Proceedings of the North Dakota Academy of Sciences, Vol. 27, No. 2, pp. 40-49.

_____________. (1977). "Weather Influences on Nocturnal Bird Mortality at a North Dakota Tower," The Wilson Bulletin, Vol. 89, No. 2, pp. 291-299.

Barrett, J. O. (1881). History of Traverse County, West Publishing Co., St. Paul, Minnesota.

Behler, J.L. and F.W. King (1979). The Audubon Society Field Guide to North American Reptiles and Amphibians, Alfred A. Knopf, New York.

Beissel, Dennis, Barbara Biggs, Kenneth L. Brown, and Marie E. Brown (1984). Cultural Resources Investigations at the Lake Traverse-Bois De Sioux Project, Roberts County, South Dakota, Traverse County, Minnesota, University of South Dakota Archeology Laboratory, Vermillion. Submitted to the St. Paul District Corps of Engineers, Minnesota.

Bellrose, F.C. (1979). "Species Distribution, Habitats and Characteristics of Breeding Dabbling Ducks in North America," Waterfowl and Wetlands - an Integrated Review (T.A. Brookhout, ed.), Symposium Proc. 1977, North Central Section, The Wildlife Society, Madison, Wisconsin.

Bellrose, F.C. and B.A. Heister (1985). "The Central Flyway," Nature Conservancy News, Vol. 35, No. 1, pp. 4-7.

Bluemle, J.P. (1967). "Geology and Groundwater Resources of Traill County, North Dakota, Part 1: Geology," North Dakota Geological Survey, Bulletin 53.

____________. (1973). "Geology of Nelson and Walsh Counties, North Dakota, Part 1: Geology," North Dakota Geological Survey, Bulletin 57.

____________. (1975). "Geology of Griggs and Steele Counties, North Dakota, Part 1: Geology," North Dakota Geological Survey, Bulletin 64.

____________. (1977). "The Face of North Dakota: The Geologic Story," North Dakota Geological Survey Educational Series, Bulletin 11.

Bluemle, J.P. (1982). "Bedrock Geologic Map of North Dakota," North Dakota Geological Survey, Miscellaneous Map 21.

Boyd, R.J. (1978). "American Elk," Big Game of North America: Ecology and Management, (Schmidt, J.L. and D.L. Gilbert, eds.), Stackpole Books, Harrisburg, Pennsylvania.

Boyd, Warren (1986). North Dakota Division of Employment Security, Research and Statistics Department, personal communication.

Brewster, W.G., Gates, J.M. and L.D. Flake (1976). "Breeding Waterfowl Populations and Their Distribution in South Dakota," J. Wildl. Manage., Vol. 40, pp. 50-59.

Briggs, Harold E. (1930). "The Great Dakota Boom, 1876 to 1886," North Dakota Historical Quarterly, Vol. 4, pp. 78-109.

Brophy, John A. and John P. Bluemle (1983). "The Sheyenne River: its Geological History and Effects on Lake Agassiz," Glacial Lake Agassiz, T. J. Teller and Lee Clayton (eds.), pp. 173-186. Geological Association of Canada Special Paper 26.

Buechler, Jeff (1984). Working draft of a management plan for archaeological resources in South Dakota, Office of the State Archaeologist, Fort Meade, South Dakota.

Chamberlain, Louis M. (1986). Environmental Engineer, Regulatory Compliance Section, Division of Air Quality, Minnesota Pollution Control Agency, Roseville, Minnesota, personal communication.

Cole, Kenneth W. (1968a). The Forest River Survey, 1967, University of North Dakota, Department of Sociology and Anthropology, Laboratory of Anthropology, Field Reports in Archaeology 1, Grand Forks, North Dakota.

____________. (1968b). The Goose River Survey, 1967, University of North Dakota, Department of Sociology and Anthropology, Laboratory of Anthropology, Field Reports in Archaeology 2, Grand Forks, North Dakota.

____________. (1968c). The Turtle River Survey, 1967, University of North Dakota, Department of Sociology and Anthropology, Laboratory of Anthropology, Field Reports in Archaeology 5, Grand Forks, North Dakota.

Collins, R. (1986). U.S. Fish and Wildlife Service, personal communication

Commonwealth Associates--Donald S. Weir, principal investigator (1981). A Cultural Resource Inventory - St. Vincent to St. Clair Gas and Sault Lateral Pipelines, Minnesota, Wisconsin, and Michigan, Ms. on file, Minnesota Historical Society, Fort Snelling.

Conant, R. (1975). A Field Guide to Reptiles and Amphibians of Eastern and Central North America, Houghton Mifflin Co., Boston.

Craddock, C. (1972). "Bouguer Gravity Map Showing Midcontinent Gravity High," Minnesota Geological Survey, Plate 2.

Crawford, R.L. (1978). "Autumn Bird Casualties at a Northwest Florida TV Tower: 1973-1975," The Wilson Bulletin, Vol. 90, No. 3, pp. 335-478.

Downey, J.S. (1971). "Groundwater Basic Data, Nelson and Walsh Counties, North Dakota," North Dakota Geological Survey, Bulletin 57-Part II.

_____________. (1973). "Groundwater Resources, Nelson and Walsh Counties, North Dakota," North Dakota Geological Survey, Bulletin 57-Part III.

Downey, J.S. and C.A. Armstrong (1977). "Groundwater Resources of Griggs and Steele Counties, North Dakota," North Dakota Geological Survey, Bulletin 64-Part III.

Downey, J.S., R.D. Hutchinson and G.L. Sunderland (1973). "Groundwater Basic Data for Griggs and Steele Counties, North Dakota," North Dakota Geological Survey, Bulletin 64-Part II.

Duebbert, H.F. (1981). "Breeding Birds on Waterfowl Production Areas in Northeastern North Dakota," Prairie Nat., Vol. 13, pp. 19-22.

Enrud, H. (1986). Roadway Superintendent, Nelson County, North Dakota, personal communication.

Eyre, F.H. (1980). Forest Cover Types of the United States and Canada, Society of American Foresters.

Faanes, C.A. (1984). "Birds and Powerlines in North Dakota," North Dakota Outdoor, pp. 12-14.

Flint, Richard F. (1955). Pleistocene Geology of Eastern South Dakota, U.S. Geological Survey, Professional Paper 262.

Fox, Richard A., Jr. (1980). Cultural Resource Inventory of the Proposed Saskatchewan Intertie Transmission Line Right-of-way, Northwestern North Dakota, Department of Anthropology and Archaeology, University of North Dakota, Grand Forks, submitted to Basin Electric Power Cooperative, Bismarck, North Dakota.

Franzmann, A.W. (1978). "Moose," Big Game of North America: Ecology and Management, (Schmidt, J.L. and D.L. Gilbert, eds.), Stackpole Books, Harrisburg, Pennsylvania.

Frison, George C. (1978). Prehistoric Hunters of the High Plains, Academic Press, New York.

Gauthreaux, S.A. (1978). "Migratory Behavior and Flight Patterns," Impacts of Transmission Lines on Birds in Flight, Proceedings of a Workshop, U.S. Fish and Wildlife Service, U.S. Department of the Interior, pp. 12-26.

Gilman, Rhoda, Carolyn Gilman and Deborah M. Stultz (1979). The Red River Trails: Oxcart Routes between St. Paul and the Selkirk Settlement 1820-1870, Minnesota Historical Society, St. Paul.

Granger, Susan (1985). Traverse County Historic Sites Survey, 1983-1984, conducted for the Minnesota State Historic Preservation Office in cooperation with the Traverse County Historical Society. On file at the Minnesota Historical Society, Fort Snelling.

Halls, L.K. (1978). "White-tailed Deer," Big Game of North America: Ecology and Management (J.L. Schmidt and D.L. Gilbert, eds.), Stackpole Books, Harrisburg, Pennsylvania.

Hannus, L. Adrien (1982). Cultural Resources Investigations of the South Dakota Segment of the Northern Border Pipeline Project (5 volumes), Northern Plains Natural Gas Co., Omaha, Nebraska.

Hansen, D.E. and J. Kume (1970). "Geology and Groundwater Resources of Grand Forks County, North Dakota, Part 1: Geology," North Dakota Geological Survey, Bulletin 53.

Hanson, Doug (1986). South Dakota Game, Fish and Parks Department, personal communication.

Haynes, C. Vance, Jr. (1966). "Elephant Hunting in North America," Scientific American, Vol. 214, No. 6, pp. 104-112.

Heynick, L.N. (in process). "Critique of Literature on Bioeffects of Radiofrequency Radiation: A Comprehensive Review Pertinent to Air Force Operations."

Heynick, L.N. and P. Polson (1983). "Bioeffects of Radiofrequency Radiation: A Review Pertinent to Air Force Operations," USAF School of Aerospace Medicine, Brooks AFB, Texas, Report USAFSAM-TR-83-1.

Hier, D. (1986). Highway Engineer, Traill County, North Dakota, personal communication.

Higgins, K.F., G.W. Fulton and W.T. Barker (1984). "Wetlands and Forage," U.S. Fish and Wildlife Service, South Dakota Cooperative Wildlife Research Unit, South Dakota Cooperative Extension Service, Pamphlet FS 826.

Hobbs, H.C. and J.E. Goebel (1982). "Geologic Map of Minnesota - Quaternary Geology," Minnesota Geological Survey, Map S-1.

Holzkamm, Tim E. (1983). "Eastern Dakota Population Movements and the European Fur Trade: One More Time," Plains Anthropologist, Vol. 28, pp. 225-233.

HUD (U.S. Department of Housing and Urban Development) (1977). "Flood Hazard Boundary Maps, Traverse County, Minnesota, Unincorporated Area."

____________. (1980a). "Flood Hazard Boundary Maps, Grand Forks County, North Dakota, Unincorporated Area."

____________. (1980b). "Flood Hazard Boundary Maps, Traill County, Unincorporated Area."

____________. (1981a). "Flood Hazard Boundary Maps, Pennington County, Minnesota, Unincorporated Area."

____________. (1981b). "Flood Hazard Boundary Maps, Walsh County, North Dakota, Unincorporated Area."

____________. (1983). "Flood Insurance Rate Map, Polk County, Minnesota, Unincorporated Area."

Huggett, William (1986). Minnesota Division of Economic Services, personal communication.

ICBO (International Conference of Building Officials) (1985). Uniform Building Code - 1985 Edition, Whittier, California.

Jaroslow, B.N. (1979). "A Review of Factors Involved in Bird - Tower Kills and Mitigative Procedures," The Mitigation Symposium: A National Workshop on Mitigating Losses of Fish and Wildlife Habitats, U.S. Dept. of Agriculture, pp. 469-473.

Jenks, Albert E. (1900). "The Wild Rice Gatherers of the Upper Great Lakes; a Study in American Primitive Economics," Bureau of American Ethnology, Annual Report (for 1897-98), Vol. 19, pp. 1013-1137.

____________. (1937). "Minnesota's Browns Valley Man and Associated Burial Artifacts," American Anthropological Association, Memoir 49.

Jensen, H.M. (1967). "Geology and Ground Water Resources of Traill County, Part II - Basic Data," North Dakota Geological Survey, Bulletin 49-Part II.

Jensen, H.M. and R.L. Klausing (1971). "Geological and Groundwater Resources of Traill County, Part 3: Groundwater Resources," North Dakota Geological Survey, Bulletin 49- Part III.

Johnson, Elden. (1962). "The Prehistory of the Red River Valley," Minnesota History, Vol. 38, No. 4, pp. 157-165.

_____________. (1964a). "Copper Artifacts and Glacial Lake Agassiz Beaches," The Minnesota Archaeologist, Vol. 25, pp. 5-23.

_____________. (1964b). "Twenty New Radiocarbon Dates from Minnesota Archaeological Sites," Minnesota Archaeologist, Vol. 26, No. 2, pp. 34-49.

_____________. (1973). The Arvilla Complex, Minnesota Prehistoric Archaeology Series 9, Minnesota Historical Society, St. Paul.

Johnson, Jerome E. (1986). "North Dakota Farm Land Values in 1985," North Dakota Farm Research, Vol. 43, No. 4.

Keenlyne, K.D. (1986). Field Supervisor, ES, South Dakota Field Office, U.S Fish and Wildlife Service, Pierre, South Dakota. Letter to S.J. Everett, SRI International.

Keller, Stephen W., and Renee Keller (1983). Volume II, James River Survey, Brown County, South Dakota, 1983, South Dakota Archaeological Research Center, Fort Meade, South Dakota.

Keller, Stephen W., and Karen P. Zimmerman (1981). Cultural Resource Investigations of the Waubay National Wildlife Refuge, Department of Anthropology, University of South Dakota, Vermillion, submitted to the U.S. Fish and Wildlife Service, Denver.

Kelly, T. E. (1968) "Geology and Groundwater Resources of Grand Forks County, Part II: Groundwater Basic Data," North Dakota Geological Survey, Bulletin 53-2.

Kelly, T.E. and Q.F. Paulson (1970). "Geology and Groundwater Resources of Grand Forks County, Part III: Groundwater Resources," North Dakota Geological Survey, Bulletin 53-Part III.

Koch, N. (1975). "Geology and Water Resources of Marshall County, South Dakota, Part I: Geology and Water Resources," South Dakota Geological Survey, Bulletin 23.

Koch, Neil C. and Bradford Wendall (1976). "Geology and Water Resources of Brown County, South Dakota," U.S. Geological Survey and South Dakota Geological Survey, Bulletin 25.

Kocp, Wayne (1986). Civil Engineer, Grand Forks Air Force Base, North Dakota, personal communication.

Krapu, G.L. (1974). "Avian Mortality from Collisions with Overhead Wires in North Dakota," Prairie Nat., Vol. 6, No. 1, pp. 1-6.

Kurcinka, J.M. (1986). Letter to S.J. Everett, SRI International, from Minnesota Department of Natural Resources, St. Paul, Minn.

Lancaster, Richard R. (1986). Statistical Analyst, Department of Public Service, St. Paul, Minnesota, personal communication.

Landis, E.R., ed. (1973). "Mineral and Water Resources of North Dakota," North Dakota Geological Survey, Bulletin 63.

Lane, Richard B. (1974). An Archaeological Surface Survey of Dome Pipeline Corporation's Proposed Pipeline Right-of-way across the State of Minnesota, May-September, 1974, Ms. on file, Minnesota Historical Society, Fort Snelling.

Larson, John (1986). Area Fisheries Manager, Minnesota Department of Natural Resources, personal communication.

Larson, Thomas K., Dori M. Penny, John D. Benko, and Ross G. Hillman (1986). The 1985 Forest River Survey: a Class II Cultural Resources Inventory, Grand Forks and Walsh Counties, North Dakota.

Lensink, Steven C. (1979). A Prehistoric Subsistence-settlement Study in the Prairie Pothole Region: Survey Sampling Design in a Nonriverine Environment, paper presented at the 37th Plains Conference, Kansas City, Missouri.

Lewis, T. H. (n.d.). T. H. Lewis Field Notebooks 10 and 31, Northwest Archaeological Surveys, Minnesota Historical Society Archives, St. Paul.

Linder, R.L. and D.E. Hubbard (1982). "Wetland Values in the Prairie Pothole Region of North America," Proceedings of Great Plains Agricultural Council, June 7-9, 1982, North Platte, Nebraska.

Lipetzky, T. (1986). North Dakota Department of Agriculture, personal communication.

Loendorf, Lawrence L. (1977). The Cultural Resource Inventory for the Proposed Channelization Work on the Turtle River, Grand Forks County, North Dakota, Department of Anthropology and Archaeology, University of North Dakota, Grand Forks, submitted to the U.S. Soil Conservation Service, Grand Forks, North Dakota.

Loendorf, Lawrence, and Kent Good (1974). The Results of the Archaeological Survey of the South Branch of the Forest River, Ms. on file, Department of Anthropology and Archaeology, University of North Dakota, Grand Forks.

Maclay, R.W., T.C. Winter and L.E. Bidwell (1968). "Water Resources of the Mustinka and Bois de Sioux Rivers Watershed, West-Central Minnesota," U.S. Geological Survey, Hydroinvestigation Atlas, HA-272.

Manson, R. (1986). U.S. Fish and Wildlife Service, Valley City, North Dakota, field office, personal communication.

McDonald, Charles M. (1986). Manager, Air Quality Service Branch, North Dakota State Department of Health, Bismarck, North Dakota, personal communication.

McDonald, J.N. (1979). "Waterfowl Collisions with Utility Wires: Two Observations on the Southern Plains," The Texas Journal of Science, Vol. 31, No. 1, pp. 369-370.

McKinnen, J. (1986). Highway Engineer, Polk County, Minnesota, personal communication.

Michlovic, Michael G. (1983). "The Red River Valley in the Prehistory of the Northern Plains," Plains Anthropologist, Vol. 28, pp. 23-31.

____________. (1984). The Archaeology of the Mooney Site (21NR29) on the Red River in Minnesota, Department of Sociology and Anthropology, Moorhead State University, Moorhead, Minnesota, submitted to the St. Paul District Corps of Engineers, St. Paul, Minnesota.

Miller, J.E. and D.L. Frink (1982). "Changes in Flood Response of the Red River of the North Basin, North Dakota - Minnesota," U.S. Geological Survey, Open-File Report, 82-774.

Minnesota Department of Agriculture (1986). Representative of Agricultural Statistics Division, personal communication.

Minnesota Department of Natural Resources (1983). Division of Waters "Protected Waters and Wetlands, Traverse County, Minnesota," Sheet 1 of 1.

____________. (1984). "Protected Waters and Wetlands, Pennington County, Minnesota," Sheet 1 of 1.

____________. (1985). "Protected Waters and Wetlands, Polk County, Minnesota," Sheet 3 of 3.

Minnesota Natural Heritage Program (1986). Over the Horizon-Backscatter (OTH-B) Radar System: Evaluation of Potential Minnesota Sites, Minnesota Department of Natural Resources.

Minnesota Pollution Control Agency (1981). "Minnesota Code of Agency Rules, Title 6, Environment, Part 4, Minnesota Water Quality Standards," (as amended through June 1981).

____________. (1984). "Minnesota Water Quality, Water Years 1982 - 1983: The 1984 Report to Congress of the United States by the State of Minnesota Pursuant to Section 305(b) of the Federal Water Pollution Control Act."

____________ (1985). "Chapter 7050. Standards for the Protection of the Quality and Purity of the Waters of the State," (as amended through July 1985).

____________ (n.d.). "Individual Sewage Treatment Systems Standards," Chapter 7080, Water Quality Division, Minnesota Department of Health.

____________. (1986). Water Quality Data, Storet Search.

Minnesota State Department of Health. (1985). Division of Water Supply and Engineering, Minnesota Public Water Supply Data

____________ (1986). Water Supply Data, Water Supply and Engineering Department, Division of Environmental Health, Minneapolis, Minnesota.

Missouri River Basin Commission (1980). "James River Basin Subregional Analysis, North Dakota - South Dakota," Water Resource Characteristics Technical Paper.

Mitchell, J.C. (1985). "Development and Application of New Radio-frequency Radiation Safety Standards," The Impact of Proposed Radio Frequency Radiation Standards on Military Operations, AGARD-LS-138, NATO Advisory Group for Aerospace R&D, Neuilly sur Seine, France.

Mooney, M.M. and G.B. Morey (1981). "Seismic History of Minnesota and its Geological Significance," Bulletin of the Seismic Society of America, Vol. 71, pp. 199-210.

National Oceanic and Atmospheric Administration (1982). "Climatology of the United States #60," National Climatic Center, Ashville, North Carolina.

Nicolai, Michele, Steve G. Sylvester, Kurt Schweigert, and Fred E. Schneider (1978). Cultural Resource Investigation of the Goose River Basin, North Dakota, Department of Anthropology and Archaeology, University of North Dakota, Grand Forks, submitted to the St. Paul District, Corps of Engineers, Minnesota.

Noble, E.A. (1973). "Mineral and Water Resources of North Dakota," U.S. Geological Survey and North Dakota Geological Survey, Bulletin 63.

North Dakota Department of Health (1984). "North Dakota 305(b) Report," Division of Water Supply and Pollution Control.

____________ (1986). Landfill Map, Division of Hazardous Waste Management and Special Studies, Bismarck, North Dakota.

Onstad, R. (1986). Highway Superintendent, Grand Forks County, North Dakota, personal communication.

Pich, R. (1986). North Dakota Game and Fish Department, personal communication.

Ranek, John (1986). South Dakota Department of Agriculture, personal communication.

Rood, Ronald J. and Vicki O. Rood (1984). Results of an Archaeological Survey along the Coteau des Prairies in Roberts and Marshall Counties, South Dakota, submitted to the South Dakota Archaeological Research Center, South Dakota Archaeological Research Center, Contract Investigation Series 103.

Roughstad, O.J. and J.R. Tester (1969). "Movements and Habitat Use of White-tailed Deer in Minnesota," Journal of Wildlife Management, Vol. 33, pp. 366-379.

Sambor, K. (1986). North Dakota Game and Fish Department, personal communication.

Schaub, L. (1986). Highway Engineer, Traverse County, Minnesota, personal communication.

Schmidt, Edgar (1986). North Dakota Water Commission, personal communication.

Schneider, Fred (1982). "A Preliminary Investigation of Paleo-Indian Cultures in North Dakota," Manitoba Archaeological Quarterly, Vol. 6, pp. 16-43.

Sigstad, John S. and Joanita Sigstad (editors) (1973). Archaeological Field Notes of W. H. Over, Office of the South Dakota State Archaeologist, Research Bulletin Number 1.

Sims, P.K. (1970). "Geologic Map of Minnesota - Bedrock Geology," Minnesota Geological Survey, Plate 1.

Sims, P.K. and G.B. Morey, eds. (1972). Geology of Minnesota: A Centennial Volume, Minnesota Geological Survey.

Smith, R.L. (1980). Ecology and Field Biology, Harper and Row, New York.

Soil Conservation Service (1972). "Soil Survey of Walsh County, N.D.," U.S. Department of Agriculture.

_____________. (1975). "Soil Survey of Marshall County, S.D.," U.S. Department of Agriculture.

_____________. (1977). "Soil Survey of Traill County, N.D.," U.S. Department of Agriculture.

_____________. (1981). "Soil Survey of Grand Forks County, N.D.," U.S. Department of Agriculture.

_____________. (1984). "Soil Survey of Pennington County, M.N.," U.S. Department of Agriculture.

South Dakota Department of Water and Natural Resources. (1983). "South Dakota's Public Water System Data," Office of Drinking Water.

_____________. (1984a). "South Dakota Water Quality, Water Years 1982 - 1983: The 1984 Report to Congress of the United States by the State of South Dakota Pursuant to Section 305(b) of the Federal Water Pollution Control Act."

_____________. (1984). "South Dakota Air Monitoring Network Review," Pierre, South Dakota.

_____________. (1986). "South Dakota Air Monitoring Network Review," Pierre, South Dakota.

South Dakota State Planning Bureau (1975). "South Dakota Facts."

SRI International (1986). "Man-Made Hazards to Birds in Flight," Research Report.

Stewart, R.E. and H.A. Kantrud (1971). "Classification of Natural Ponds and Lakes in the Glaciated Prairie Region," U.S. Fish and Wildlife Service, Resource Publication 92.

____________. (1972). "Vegetation of Prairie Potholes, North Dakota, in Relation to Quality of Water and Other Environmental Factors," U.S. Geological Survey, Professional Paper 585-D.

____________. (1974). "Breeding Waterfowl Populations in the Prairie Pothole Region of North Dakota," Condor, Vol. 76, No. 1.

Stoudt, J.H. (1971). "Ecological Factors Affecting Waterfowl Production in the Saskatchewan Parklands," U.S. Fish and Wildlife Service, Resource Publication 99.

Stuchly, M.A. and M.H. Repacholi (1968). "Microwave and Radiofrequency Protection Standards," Microwave Bioeffects and Radiation Safety, Transactions of the IMPI, Vol. 8, pp. 95-101.

Thompson, L.S. (1978). "Transmission Line Wire Strikes: Mitigation through Engineering Design and Habitat Modification," Impacts on Transmission Lines on Birds in Flight, Proceedings of a Workshop, U.S. Fish and Wildlife Service, U.S. Department of the Interior, pp. 27-52.

Tiner, Ralph W., Jr. (1984). "Wetlands of the United States: Current Status and Recent Trends," U.S. Fish and Wildlife Service.

Tweton, D. Jerome (1978). Known Historic Site Survey of 32 Eastern North Dakota Counties, Department of History, University of North Dakota, Grand Forks, submitted to the Regional Environmental Assessment Program Commission, Bismarck, North Dakota. (Detailed site locational information on file at the State Historical Society of North Dakota, at Bismarck.)

University of North Dakota (1983). Statistical Abstract of North Dakota 1983, Bureau of Business and Economic Research.

U.S. Army Topographic Command Maps (1975). Thief River Falls, Minnesota, North Dakota; Grand Forks, North Dakota, Minnesota; Fargo, North Dakota, Minnesota; and Milbank, South Dakota, Minnesota, North Dakota.

U.S. Department of Agriculture (1982). Census of Agriculture.

U.S. Department of Commerce (1982). Bureau of the Census, Census of Construction Industries, North Central Area.

____________. (1983). County and City Data Book 1983, Bureau of the Census.

____________. (1986). "Survey of Current Business," Bureau of Economic Analysis.

USFWS (U.S. Fish and Wildlife Service) (1985). "Pennsylvania Modified 1980 Habitat Evaluation Procedure."

USGS (U.S. Geological Survey) (1962). "Evaporation from the Seventeen Western States," Professional Paper 272-D, Plate 3.

__________. (1968). "Water Resources of the Mustinka and Bois-de Sioux Rivers Watershed, West Central Minnesota," Hydrogeologic Atlas-272.

__________. (1970). "Water Resources of the Red Lake River Watershed, Northwestern Minnesota," Hydrogeologic Atlas - 346.

__________. (1980). "Water Resources Data for North Dakota, Water Year 1980," U.S. Geological Survey Water-Data Report, ND-80-1.

__________. (1983). "Water Resources Data, Minnesota, Water Year 1983, Volume I - Great Lakes and Souris-Red-Rainy River Basins," U.S. Geological Survey Water-Data Report, MN-83-1.

Welford, R.F. (1986). Letter to S.J. Everett, SRI International, from U.S. Fish and Wildlife Service, St. Paul Field Office, St. Paul, Minnesota.

Weller, M.W. and L.H. Fredrickson (1974). "Avian Ecology of a Managed Glacial Marsh," Living Bird, Vol. 12, pp. 269-291.

Weller, M.W. and C.E. Spatcher (1965). "Role of Habitat in the Distribution and Abundance of Marsh Birds," Iowa Agriculture and Home Economics Experiment Station, Special Report No. 43.

Wetstein, Douglas W. (1986). Natural Resources Analyst, Division of Air Quality and Solid Waste, Department of Water and Natural Resources, Pierre, South Dakota, personal communication.

Whitaker, J.O., Jr. (1980). The Audubon Society Field Guide to North American Mammals, Alfred A. Knopf, New York.

Wilford, Lloyd A. (1970). Burial Mounds of the Red River Headwaters, Minnesota, Minnesota Prehistoric Archaeology Series 5, Minnesota Historical Society, St. Paul.

Winchell, Newton H., (ed.) (1911). The Aborigines of Minnesota, Minnesota Historical Society, St. Paul, Minnesota.

Winter, T.C. and R.D. Benson et al. (1984). "Synopsis of Groundwater and Surface-Water Resources of North Dakota," U.S. Geological Survey, Open-File Report, 84-732.

Woolworth Research Associates (1978). A Report on an Archaeological and Historical Reconnaissance Survey of the Great Lakes Gas Transmission Company's Pipeline Route in North Dakota and Minnesota, Woolworth Research Associates, White Bear Lake, Minnesota, submitted to the Great Lakes Gas Transmission Co., Detroit, Michigan.

Appendix A

RADAR AND ANTENNA CHARACTERISTICS

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Appendix A

RADAR AND ANTENNA CHARACTERISTICS

A.1 Introduction

This appendix describes the principal characteristics of the OTH-B radar system. It is quite similar to an experimental radar system that was installed and subjected to extensive testing at sites near Columbia Falls and Moscow, Maine. The Maine facility is now under construction as an operational radar system, designated the AN/FPS-118, with 180° coverage. A second AN/FPS-118 system in northern California and southern Oregon is in the site preparation phase.

The Central Radar System (CRS) would be similar to the systems under construction in Maine and on the West Coast, with the possibility of design changes to improve system performance. The principal difference is that this system would cover 240° in azimuth and would use a somewhat wider frequency band. The Alaskan Radar System would be similar in the preposed design and operation.

A conventional radar operates by transmitting a pulse of electromagnetic energy and then waiting to receive energy reflected back to its antenna from some object (target) illuminated by the pulse. Such a radar interprets the time interval between the transmitted pulse and the return as a measure of the distance from the radar to the target. The OTH-B system achieves the same goal by a somewhat different method (see Section A.3).

It is highly advantageous for a radar to concentrate its transmitted energy (and to limit its receiving capability) in a relatively narrow beam. A narrow beam permits greater certainty regarding the direction in which the energy was sent and from which it returned, thus better defining the direction from the radar to the target. A narrow beam also conserves the available energy because it concentrates it into a single direction; finally, it permits reception of weaker returns from a particular direction by discriminating against electromagnetic noise or extraneous, interfering signals that may arrive from other directions.

The resulting OTH-B beam is stepped in azimuth in increments of 7.5°; thus, 8 steps are required to cover the 60° sector assigned to each antenna array. The beam dwells on a particular azimuth for an interval long enough to obtain a return, but not exceeding 10 seconds. Therefore, a given azimuth will be revisited in an interval not exceeding 80 seconds.

Radars have long used parabolic reflectors, or dishes, to form beams in the same manner that the silvered reflector of an automobile headlight forms a beam from the light emanating from the lamp's filament. To move the beam, the radar dish and the radiating element are typically rotated at a particular fixed rate to sweep past a given azimuth every second or so. The need for mechanical motion limits the speed of scanning in such radars.

The OTH-B radar differs from a conventional, microwave radar in many important details. Instead of a single antenna, it uses separate antenna systems for transmitting and receiving; instead of being together, the transmitting and receiving systems are separated by many miles; instead of radiating power in brief pulses separated by long periods of rest, it radiates continuously; instead of using frequencies within a relatively narrow band, it uses frequencies that may vary through a very wide range; and instead of following a straight line to and from the target, the waves are refracted by the ionosphere and reach targets far beyond the horizon of the radar site.

A.2 The Frequency Band

A.2.1 Equipment Capability

To perform its function, the OTH-B radar can choose any frequency in the 5.0- to 28.0-MHz band, corresponding to wavelengths in the 60- to 10.7-m range.* These wavelengths are as much as 600 times longer than those used by a typical "S-band" microwave radar with a wavelength of 10 cm and a frequency of 3000 MHz. Unlike S-band waves, these relatively long waves are bent by the ionosphere and return to the earth well beyond the horizon, where they can reach and detect targets (see Section A.5). The properties of these waves create many difficult design problems, however. The frequency used at any particular time is chosen to optimize results; the best frequency depends on the object to be detected and the atmospheric conditions that prevail.

A.2.2 Excluded Frequencies

Although the transmit antenna system of the OTH-B radar system can generate and radiate any frequency between 5.0 and 28.0 MHz, numerous frequency bands within this overall range are assigned to other users and avoided by the OTH-B system. A representative list of such frequencies is given in Table A-1.

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*As noted later, the system is programmed to avoid frequencies assigned to other services or on which excessive interference exists.

Table A-1

DISTRESS, CALLING, AND GUARDED FREQUENCIES

Frequency (MHz)	Allocated Services
5.000 ± 0.005	Standard Frequency
5.320 ± 0.005	International Ice Patrol
5.680 ± 0.020	SAR Control--Atlantic and Pacific
5.6814 ± 0.020	SAR Control--Atlantic and Pacific
6.204 ± 0.020	SAR Control--Atlantic and Pacific
6.2054 ± 0.020	SAR Control--Atlantic and Pacific
6.273 ± 0.010	Aircraft Communication to Maritime Mobile Stations
7.5084 ± 0.020	Hurricane Warning Net
7.530 ± 0.020	Emergency Net--Atlantic and Pacific Area
8.364 ± 0.020	SAR Control--Atlantic and Pacific
8.502 ± 0.005	International Ice Patrol
8.7564 ± 0.005	International Ice Patrol
10.000 ± 0.005	Standard Frequency
11.515 ± 0.020	Emergency Net--Atlantic Area
12.150 ± 0.020	Emergency Net--Atlantic Area
12.546 ± 0.010	Aircraft Communication to Maritime Mobile Stations
12.750 ± 0.005	International Ice Patrol
14.993 ± 0.005	Mobile Distress and Calling
15.000 ± 0.010	Standard Frequency
16.728 ± 0.010	Aircraft Communication to Maritime Mobile Stations
18.1975 ± 0.020	Emergency Net--Atlantic Area
18.7225 ± 0.020	Emergency Net--Pacific Area
19.993 ± 0.005	Mobile Distress and Calling Standard Frequency
20.000 ± 0.005	Standard Frequency
20.007 ± 0.020	SAR Control--Astronauts and Space Vehicles
22.245 ± 0.010	Aircraft Communication to Maritime Mobile Stations
25.000 ± 0.005	Standard Frequency

Note: Bandwidths are representative.

A.3 The Modulation

Conventional radar systems use pulse modulation (i.e., they switch the transmitter off and on, generating pulses that are brief compared to the intervening intervals) and determine the range or distance to a particular target by measuring the time that elapses between the departure and the return of a pulse. A disadvantage of this procedure is that the transmitter and all its associated components must be capable of handling peak power levels that are much higher than the average levels. The OTH-B system overcomes this difficulty by continuously transmitting a signal with a frequency that varies with time at a constant rate (linear sawtooth FM). The difference between the frequency being returned from a target and the frequency being transmitted at any instant is a measure of the time delay and hence the target distance. Radars of this kind are often called FM/CW (frequency modulated/continuous wave) systems.

Details of the waveform used are shown in Figure A-1. The center frequency, f_o, is selected in 1-Hz increments to optimize detection in the preferred range of distances. The extent of the frequency deviation or occupied bandwidth B and the waveform repetition frequency that sets the time duration T are independently chosen from the values presented in Table A-2.

Table A-2

MODULATION PARAMETERS OF THE OTH-B RADAR

Occupied Bandwidth, B (kHz)	Waveform Repetition Frequency (Hz)
5	10 to 20 Hz, 2.5-Hz steps
10	
20	20 to 60 Hz, 5-Hz steps
40	

A.4 Separation of Sites

In conventional, pulsed radars, the transmitter is silent (turned off) most of the time; in these intervals, the receiver can "listen" for weak echoes that are returned from distant objects. Because OTH-B modulation provides no such quiet times, and the strong transmitted signals would overload any sensitive nearby receiver, the receiving and transmitting systems must be separated by many miles. In this way, the signals that pass directly from transmitter to receiver are weakened enough to avoid overloading and desensitizing the receiver.

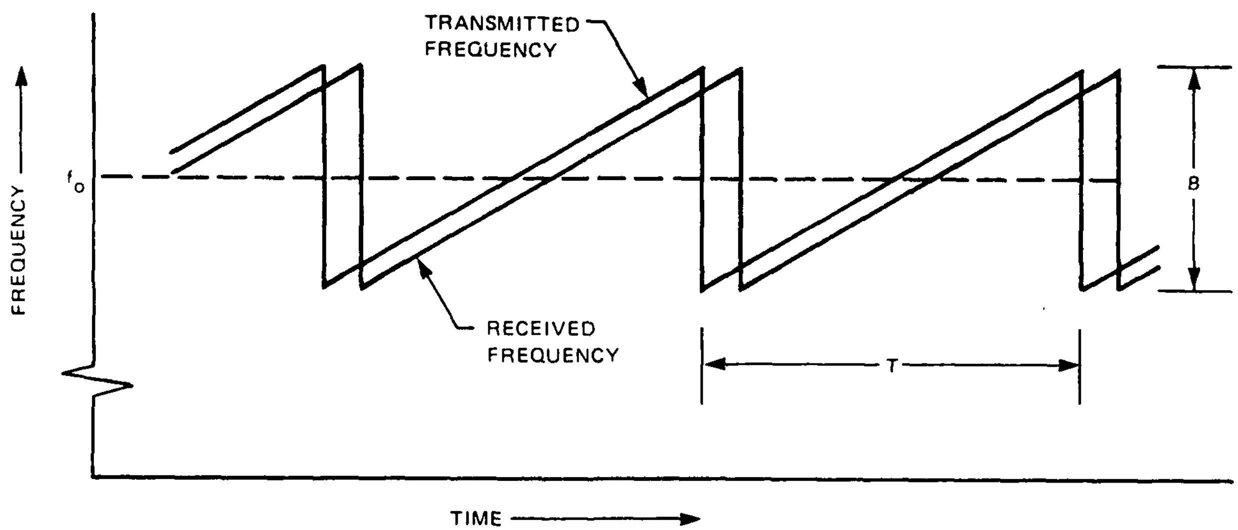

FIGURE A-1 TYPICAL MODULATION WAVEFORM OF OTH-B RADAR

A.5 Propagation

Because microwave signals travel along paths that are almost straight, microwave radar systems are limited to line-of-sight paths. In contrast, radio waves with frequencies in the general range of 5 to 28 MHz are refracted in the ionosphere, which is an ionized layer at an altitude of about 200 miles; they return to the earth's surface at a distance of about 1,000 miles. Any large object such as a ship or airplane that is on or near the surface at ranges between about 500 and 2,000 miles will reflect some incident energy and return a very small fraction of it to the receiving antenna.

The properties of the ionosphere depend on latitude and longitude, the time of day and year, sunspots, and other influences. They are constantly changing and not easily predictable. The frequency and modulation that give the best radar performance depend on existing ionospheric conditions. These considerations force the radar designer to provide great flexibility in the choice of frequency and modulation. The OTH-B radar system has the necessary flexibility.

A.6 The Antennas

To concentrate an adequate power density on distant targets, the OTH-B radar must use a transmit antenna that is both large and efficient. These considerations dictate the choice of multiple-element arrays. Moving such arrays to steer the beam is impractical; therefore, beam steering is accomplished by varying the phase (timing) of the currents delivered to the various elements.

Because long wavelengths and high levels of power are used, the elements of the transmit antenna array are large and expensive; consequently, using many elements is impractical, and the directional accuracy of the transmit antenna array is relatively low. To compensate, the OTH-B system uses receive antenna arrays with numerous elements and a high degree of directivity. In the central United States, the receive antenna system would consist of four arrays or antenna faces, each covering 60° of azimuth and the full frequency band. Although essential to the operation of the system, the receive antenna system is not discussed in this appendix because it does not radiate power.

A.6.1 The Transmit Antenna Array

Because it is impractical to design a single transmit antenna array that achieves the objectives of the OTH-B radar throughout the entire band of assigned frequencies, four antenna arrays consisting of six separate subarrays are used. Only one subarray in each face transmits at any given time. Each subarray consists of 12 elements, uniformly spaced in a plane in front of a vertical conducting backscreen. Each of the six subarrays that make up one antenna face is identified by a letter from A to F; all are aligned over a common groundscreen. Each subarray serves

a scan sector of 60° and a specific band of frequencies. Thus, there are 4 sets of 6 subarrays, for a total of 24 transmitting antenna subarrays. Both the groundscreen and backscreen are constructed of corrosion-resistant wire mesh. The width (in the smaller dimension) of the groundscreen is 750 ft. The height of the backscreen varies from band to band, according to the wavelength.

A.6.2 Formation of the Beam

The currents that are forced to flow in the dipole elements of a driven array induce currents in adjacent portions of the backscreen and groundscreen; these induced currents contribute to the total radiation. The situation is comparable to a lamp bulb near a corner where two mirrors meet at right angles. A single bulb appears as four bulbs, and the brightness is enhanced by a factor of four. The mathematical procedure based on this idea is called the method of images, and radiation is calculated by adding fictional "image" radiators at suitable locations.

If the antenna was located on a flat, perfectly conducting surface, the radiation intensity would be a maximum in the horizontal direction.* Because of the imperfect conductivity of the earth, the lower rays are absorbed or "scraped off," and maximum radiation intensity occurs at an elevation angle of about 10°.

This concept is represented in Figure A-2, which illustrates how the main beam of the OTH-B radar is formed. For clarity, the representation is limited to band E and to the special case in which all elements are driven in the same phase so that the beam axis is perpendicular to the backscreen. The (horizontal) 3-dB beamwidth of a 12-element array of this kind is 8.4°; that is, the intensity of the beam decreases by a factor of two at angles $\pm$ 4.2° from the beam axis.

A.6.3 Beam Shaping

The highest possible gain, corresponding to maximum power density on a distant target, is achieved by delivering an equal amount of power to each of the 12 elements in the operating array. Although this is usually a desirable operating condition, better results can sometimes be achieved by reducing the amount of power delivered to the elements farthest from the array center. Doing so widens the beam and reduces the power density but greatly reduces the power in the sidelobes. The calculations in Appendix B are based on uniform power distribution, which creates maximum values of both instantaneous maximum and time-averaged power density at all locations near the transmitting antenna.

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*This statement is strictly accurate only for bands E and F that use vertical radiating elements.

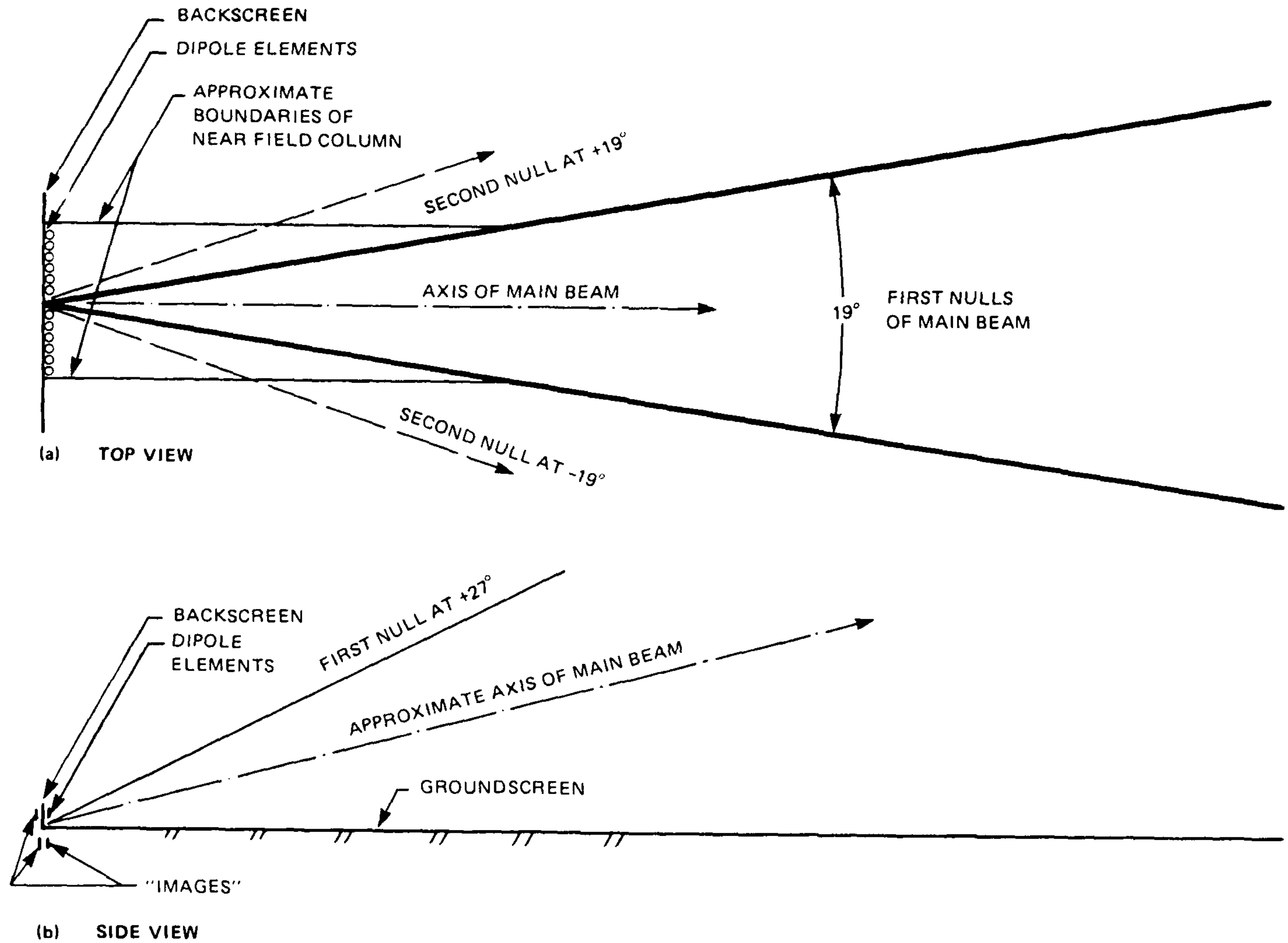

FIGURE A-2 FORMATION OF MAIN BEAM OF OTH-B RADAR (BAND E)

A.6.4 Grating Lobes

If the spacing of the antenna elements in a phased array such as that of OTH-B exceeds half a wavelength, additional lobes (known as grating lobes) can appear in the antenna radiation pattern. They are formed by the radiation from the elements adding in phase and forming additional wavefronts in directions for which the relative path lengths are integral multiples of one wavelength. When circumstances permit, grating lobes first form parallel to the array face (i.e., at 90° from the boresight direction), at the highest operating frequency of the array, and when the main beam is at the maximum scan angle. Unless suppressed in some way (e.g., by the directional pattern of the individual radiating elements), the grating lobes could have an intensity equal to that of the main beam. In the AN/FPS-118 radar, and in any practical phased array system, the element spacing is chosen to prevent grating lobes from forming.

In the arrays of the OTH-B radar, the element spacing is approximately 0.58 wavelengths at the highest frequency in each band, and the maximum scan angle is 30°. Taken together, these limitations preclude the formation of grating lobes.

A.7 The Sounders

Associated with each face of the transmitting antenna is an oblique-incidence sounder that consists of a swept-frequency transmitter and a broadband antenna. The frequency of the sounder is swept continuously from 2 to 30 MHz at a rate of 100 kHz/s. Sounder transmissions are locked out when the sweep generator passes through excluded frequencies. The functions of the sounder are to probe the path to and from the target area and to provide data that will assist in choosing the best frequency for the radar transmitter. The power radiated by the sounder is 10 kW, and the gain of the sounder antenna is less than that of the main antennas. Therefore, the sounders make a negligible contribution to the total RFR and are not given further consideration.

A.8 System Parameters

The characteristics of the OTH-B radar system described in this appendix were obtained from the OTH-B program office, Hanscom Air Force Base, Massachusetts (Snyder, 1982) and recently reconfirmed (Stevenson, 1986). These characteristics are listed in Table A-3.

Under typical operating conditions, the two faces of the transmitting antenna system radiate simultaneously and continuously, usually on different frequencies. Each face is capable of radiating as much as 1.2 MW. However, each radiated power can be reduced in 1-dB (20%) steps by as much as 15 dB. Thus, the power radiated by each face may be as small as 37 kW. The power used for each 7.5° surveillance sector is independently chosen to optimize system performance. Consequently, the total power being radiated at any instant may vary from 148 kW to 4.8 MW, but will rarely approach either limit.

Table A-3

PARAMETERS OF THE OTH-B RADAR SYSTEM
(per 60° sector)

System Characteristics	Value
Continuous wave power	
Maximum	1.2 MW
Minimum	37 kW
Antenna gain, mainlobe maximum[a]	
Ratio	160
Decibels	22
Antenna gain, sidelobe maximum[b]	
Ratio	8
Decibels	9
Antenna gain, backlobe maximum[b]	
Ratio	1.6
Decibels	2
Half-power beam width	8.4°
Dwell time, each azimuth, maximum (s)	10
Revisit time, maximum (s)	80

[a]All gain figures are stated relative to an isotropic distribution (uniform in all directions) and represent an average value over the operating frequency band.

[b]The term "sidelobe" is used here to refer to any radiation in front of the backscreen other than the mainlobe, whereas "backlobe" denotes any radiation behind the backscreen.

Each antenna scans an azimuth sector of 60° in increments of 7.5°. Each face contains 6 arrays, each consisting of 12 similar dipole radiators; in each face, only 1 of the 6 arrays operates at a given time, the choice depending on the frequency to be used. Normally, the 12 dipoles are allotted equal amounts of power; in some cases, better results are obtained by reducing the power delivered to some dipoles, which reduces the relative intensity of the sidelobes.

The maximum power density for sidelobes shown in Table A-3 is a factor of 20 smaller than the maximum power density in the mainlobe, and the backlobes (antenna lobes radiating behind the backscreen) have a maximum power density a factor of 100 smaller than the mainlobe maximum.

A.9 References

Snyder, A. L., "System Specifications for the Over-The-Horizon Backscatter Operational Radar System," U.S. Air Force Electronic Systems Division, Hanscom AFB, MA (3 June 1982).

Stevenson, R. Bruce, MITRE Corporation, Bedford, MA, personal communication (June 1986).

Appendix B

CALCULATION OF RADIOFREQUENCY RADIATION INTENSITIES

CONTENTS

ILLUSTRATIONS

TABLES

UNITS OF MEASUREMENT AND SYMBOLS

A	Area of array face
C	Velocity of light = 3×10^8 m/s
D	Effective length of each array
E	Electric field intensity (volts/meter)
F	Midband frequency of each array (MHz)
f	Frequency (hertz)
G	Antenna gain (ratio)
H	Effective height of each array
Hz	Hertz
J	Skin depth (meters)
K	Dielectric constant
L	Wavelength = C/f
m	Meters; milli (as a prefix)
N	Attenuation (nepers/meter)
P	Radiated power (watts)
R	Distance from point to array backscreen (ft)
R_s	Surface resistance (ohms)
S	Siemens
s	Seconds
S_b	Conductivity of vegetation
S_g	Conductivity of ground
u	Magnetic permeability = 1.26×10^{-6} henry per meter
U	Power density (mW/cm^2)
V	Volts
W	Watts
Z	Azimuth from boresight direction (degrees)

$\pi = 3.1416$

Appendix B

CALCULATION OF RADIOFREQUENCY RADIATION INTENSITIES

B.1 Introduction

In this appendix, an analytic procedure for calculating the intensity of radiofrequency radiation (RFR) in the vicinity of the OTH-B radar is developed. Data obtained from the OTH-B Program Office, Hanscom Air Force Base, Massachusetts (Snyder, 1982; Stevenson, 1986), and the General Electric Company (Scott, 1982) are combined with information available in textbooks and technical journals to develop mathematical expressions that permit calculation of RFR intensity at specific locations. The first six sections are devoted to analysis; the remaining sections use the resulting analytic expressions to determine values for the maximum electric field intensity, maximum power density, and average power density at selected points in the vicinity of the radar. Power densities at the center of the beam are also calculated to provide a basis for estimating their effect on the personnel and electronic systems in aircraft and on birds.

This analytic technique allows predictions that are quite accurate in free space; however, the results are affected by the presence of the ground and of objects such as trees, buildings, and power lines. In the real world, the ground terrain is irregular, and objects such as trees, power lines, and other structures are randomly distributed. When they block the line of sight to the antenna, they tend to absorb, reflect, and scatter the field. In such circumstances, the strength of the field is lower than it would be in free space. In other situations, the power reflected from the earth or other objects adds to that propagated directly, thus increasing the intensity of the radiation. Under circumstances relevant to OTH-B, the electric field strength is rarely as much as doubled in this way. Field enhancement of this kind is much more important in calculations of maximum electric field strengths and power densities than of time-averaged power densities.

Power density information is presented for two cases of interest: along the axis of maximum power density of the mainlobe, and along the ground directly below that axis. Depending on the transmission frequency, the axis is elevated approximately 12° to 22°, and the mainlobe extends approximately ±4° in azimuth and ±12° in elevation about the axis. Radiation near the axis comprises the so-called "space" or "sky wave." It is relatively unaffected by the properties of the earth in the vicinity of the transmit antenna array. Radiation along the ground below the axis comprises the so-called "surface" or "ground wave." The ground wave is strongly affected by the conductivity and dielectric

constant of the ground. For points outside the 240° surveillance zone, the power density for both space and ground waves is derived from that of the mainlobe and its known relationship to backlobes and sidelobes.

This appendix develops power densities and other characteristics for a single 60° sector. It also considers array configurations in which beams from different arrays overlap. The validity of calculations based on these methods was confirmed by measurements made in the four frequency bands of the experimental radar system (ERS) at Moscow AFS, Maine (see Section B.8.3).

B.2 System Description and Calculation Methods

B.2.1 Antenna Characteristics

Designing a single transmit antenna array to accomplish the objectives of the OTH-B radar throughout the entire band of frequencies needed (5 to 28 MHz) is impractical. Consequently, in each face six separate antenna subarrays are employed, but only one is driven at any given time.

The six subarrays of each antenna face are aligned over a common groundscreen as shown in Figure B-1; each subarray serves the specific band of frequencies listed in Table B-1. Both the groundscreen and backscreen are constructed of copperweld or alumiweld wire mesh. The width (smaller dimension) of the groundscreen is 750 ft; the length is roughly 5,000 ft. The height of the backscreen varies from band to band, as shown in Table B-1. The length D of each array is taken as equal to six times the geometric mean wavelength L. This value differs slightly from the physical dimension but is sufficiently accurate for calculating RFR. Except for band F, the band-edge and midband frequencies follow a geometric progression with a ratio of 1.35.

Each subarray consists of 12 elements, uniformly spaced in a plane in front of and parallel to a vertical conducting backscreen. The radiating elements of bands E and F are vertical and produce only vertically polarized radiation; that is, the electric vector is vertical. The elements of the other bands are inclined at an angle of 45 deg and produce equal components of horizontal and vertical polarization.

Because of its configuration, each array produces a radiation field concentrated in a fan-shaped beam, narrow in azimuth, wider in elevation.

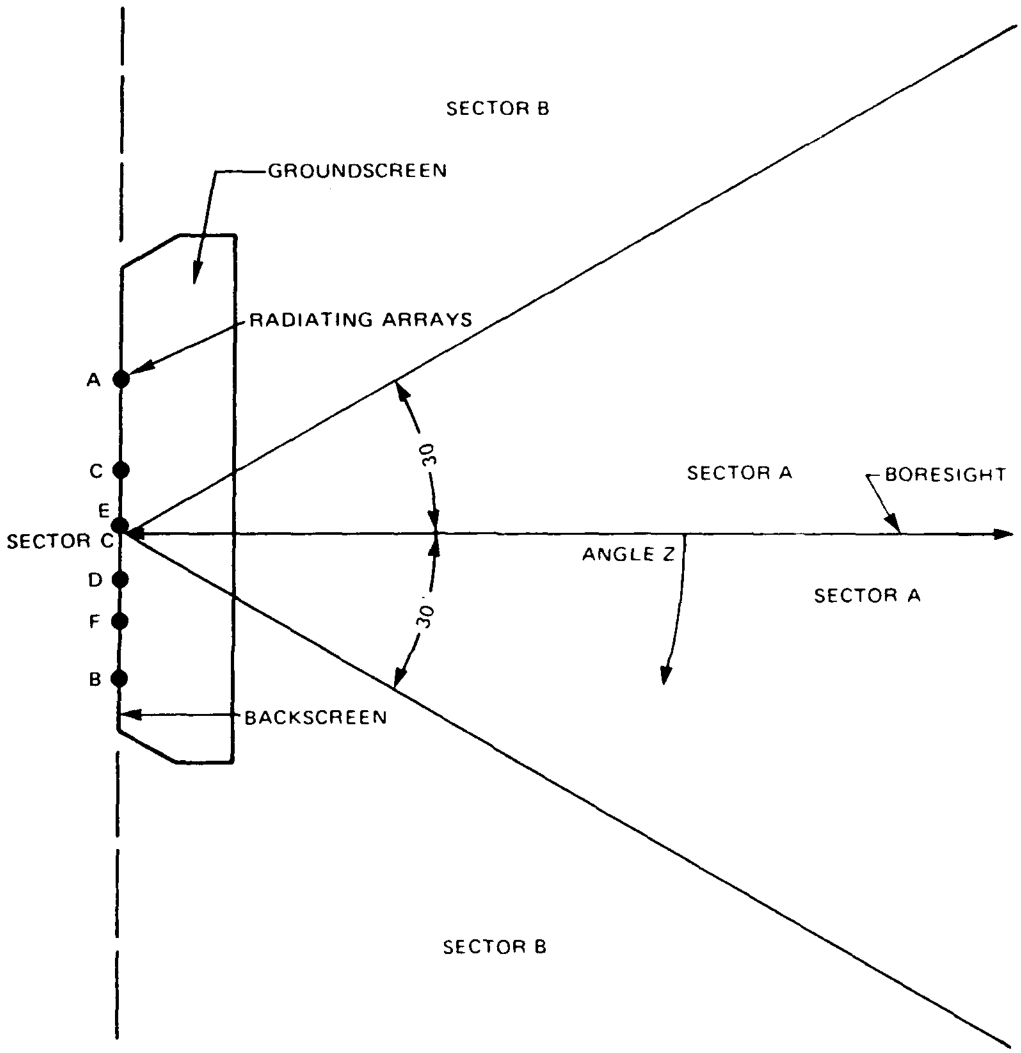

FIGURE B-1 SPACE SUBDIVISIONS USED FOR CALCULATION OF RFR (BAND E USED FOR EXAMPLE)

Table B-1

CHARACTERISTICS OF AN/FPS-118 ANTENNA ARRAYS

Band	Frequency Range (MHz)	Midband Frequency, F (MHz)	Midband Wavelength, L ft	cm	Array Length, D ft	cm	Backscreen Height (ft)
A	5.00-6.74	5.81	170	5,163	1,020	31,090	135
B	6.74-9.09	7.83	126	3,831	756	23,043	100
C	9.09-12.25	10.55	93.3	2,843	560	17,067	75
D	12.25-16.50	14.22	69.3	2,110	416	12,600	55
E	16.50-22.25	19.16	51.4	1,566	308	9,390	45
F	22.25-28.00	24.96	39.4	1,201	236	7,193	35

The azimuth of the mainlobe axis is steered $\pm 30°$ from the direction perpendicular to the backscreen by varying the phase (timing) of the signals fed to the 12 elements of the subarray that is in use. In any phased array, the projected area A varies as the cosine of the scan angle. The gain varies directly, and the horizontal beamwidth inversely with A. In the OTH-B system, the scan angle varies from 0° to 30°, with cosine values of 1.0 and 0.87, respectively. Thus, the gain and horizontal beamwidth are nearly constant throughout the sector scanned.

The resulting electromagnetic field (called RFR) of the main beam is normally described by dividing it into two regions, the near field and the far field, to which different sets of analytical conditions apply (Hansen, 1964). The boundary between the two regions is not sharply defined; rather, RFR conditions gradually change with increasing distance from the face of the antenna. Regions within or near the main beam and those at angles remote from it must also be distinguished. Different approximations apply to the different regions.

B.2.2 Frequency Bands and Radiation Zones

Because the ratio of the maximum to the minimum frequency in each band is not large, calculations based on the geometric mean frequency of each band have satisfactory accuracy for all frequencies in that band. All subsequent calculations are based on this assumption. For convenience, the mean wavelength L and the array length D are given in both feet and centimeters.

For directional antennas such as those of the OTH-B system, it is convenient to make a further distinction on the basis of azimuth, as shown in Figure B-1. Sector A, which extends $\pm 30°$ from the array boresight (i.e., the direction its points), is the scan range of the main beam of the array that is operating. Maximum values of RFR are found in this sector. The B Sectors extend from 30° to 90° on either side of the boresight. These sectors are subject to first- and higher-order sidelobes of the main beam and receive intermediate levels of RFR. Sector C covers 180° behind the backscreen; it is subject to the lowest values of RFR, which are associated with backlobes of the array.

In the following sections, the letter Z is used to designate the angle between a particular location and the boresight direction of the applicable array.

The far field is defined as a region over which the analytical conditions are constant and the fields vary inversely with distance (i.e., the power density varies inversely with the square of the distance). The distance from the array center beyond which the far field exists is conventionally taken as $2\ D^2/L$. However, far-field formulas give satisfactory approximations for all distances greater than a transition distance of $0.18\ D^2/L$.

B.2.3 Conditions and Assumptions

An antenna that is large compared to a wavelength produces a radiation field that is concentrated in a relatively small volume of space. The OTH-B transmit antenna array falls into this class. The characteristics of such a beam radiation field are determined by the following features of the array:

- Shape
- Dimensions in wavelengths
- Power distribution
- Overall efficiency.

The mathematical description of the complete field produced by large antennas is complicated. Therefore, approximate expressions have been developed to facilitate calculation. The following conditions and assumptions are applied:

(1) The array is treated as a vertical rectangular aperture with horizontal width D, height H, and area A = DH.

(2) The main beam and sidelobes are assumed to have the intensities and distributions associated with a uniformly spaced 12-element array with equal currents in all elements (Silver, 1949).

(3) The transition between near-field and far-field conditions occurs at about 0.18 $D^2/L = 6.42$ L, because $D \approx 6L$.

(4) The maximum possible on-axis power density in the near field is assumed to exist throughout the near-field column.

(5) In most cases, the greatest possible field strength near ground level will exist when the antenna main beam is pointed toward the ground.

(6) The calculation of ground-level RFR field strengths at any distance up to 25 miles from the OTH-B transmit array is based on direct- or surface-wave propagation because all other modes of propagation are weaker. Ground-level areas that are shadowed by intervening terrain will be illuminated by the diffraction mode of propagation. The RFR field strengths in such areas will be overestimated.

(7) Each array is treated separately; power addition is used to obtain RFR values in regions illuminated by more than one array.

(8) The width of the groundscreen is taken as 750 ft.

(9) Any mountain that rises sharply above ground level will be subject to values of RFR that are substantially higher than those calculated on the basis of surface-wave propagation. Upper bounds on the values of RFR that can exist at such locations are found by taking the maximum and average values of RFR that exist in the main-beam surveillance zone.

(10) The power radiated by the four sounders is small compared to that radiated by the main arrays and makes a negligible contribution to the total RFR.

B.3 Sector A

Sector A is of primary interest because it represents the range of azimuth angles scanned by the main beam and thus receives the highest levels of RFR. As previously noted, this sector must be further subdivided according to the elevation angle and the distance from the array.

B.3.1 The Far Field Region--Maximum Power Density

The far field is defined as a region over which the analytic conditions are constant and the fields vary inversely with distance. If the groundscreen were of infinite extent, the far field would start at a distance of approximately 2 D^2/L. The OTH-B transmit system involves other considerations that make this distance unimportant.

B.3.1.1 The Main Beam

A well-known and generally applicable equation for the power density on the beam axis in the far-field region of any antenna is

$$U = PG/4\pi R^2 \tag{1}$$

where U is the power density, P is the radiated power, G is the antenna gain, and R is the distance. Consistent units must be used. For the AN/FPS-118 system, P = 1.2 MW* and G = 160. To obtain results in the desired form of mW/cm^2 when the range is specified in feet, it is necessary to introduce suitable factors. To convert from megawatts to milliwatts and from square feet to square centimeters, it is necessary to multiply by 10^9 and divide by $30.48^2 = 929$. Combination of these various terms leads to a key result: for all six bands the far-field maximum power density U_1 in the center of the main beam is given by

$$U_1 = 16.5 \times 10^6/R^2 \quad mW/cm^2 \tag{2}$$

where R is the distance in feet. This is an important relationship, but its usefulness for calculating ground level power densities is limited for reasons that are given in the following sections.

B.3.1.2 The Far Field Region--Average Power Density

The principal function of the CRS is to detect aircraft and cruise missiles approaching the contiguous 48 states. To provide the needed surveillance, the transmitted beam is stepped in increments of 7.5° through the 60° azimuth range allotted to a particular array. The total (null to null) width of the main beam is about 19°; however, the effective width (measured to the half-power relative intensity points) is only 8.4°. Thus, the time-averaged power density U_2 at any given distance is 8.4/60 = 0.14 times the maximum power density in the mainbeam. Hence, from equation (2),

$$U_2 = 0.14\ U_1 = 2.3 \times 10^6/R^2 \quad . \tag{3}$$

This relationship, which applies to all six bands, is valid only in sector A and is subject to restrictions on R that are developed in subsequent sections. It neglects any contributions made by sidelobes that sweep through the sector.

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*Use of this value leads to maximum possible values of RFR. Substantially lower values of RFR will exist whenever lower power levels are used.

B.3.2 The Near-Field Region

B.3.2.1 Maximum Power Density

For the main lobe of an antenna array, idealized as a rectangular aperture, the maximum power density values on and near the beam axis in the near-field region can be calculated by a method similar to that of Hu (1961). The gain G of an antenna is related to its effective aperture area A by the equation

$$G = 4\pi A/L^2 \text{ or } A = GL^2/4\pi \ . \tag{4}$$

The aperture area A of the array is equal to its width D times its effective height H. As shown in Table B-1,

$$D \simeq 6L \quad . \tag{5}$$

Substitution of these relationships and G = 160 in equation (4) yields

$$H = 2.12\ L \quad . \tag{6}$$

The total radiated power P must pass through the area A. Thus, the average power density near the face of the array is equal to P/A. In the near-field region the power density is very uneven. In some places the fields are quite weak; in others, the field strengths are doubled, and the power density is 4 times as large as its average value. On this basis, the maximum power density U_o near the array on and near the beam axis is taken as

$$U_o = 4P/DH = 0.31P/L^2 \quad . \tag{7}$$

This quantity is given in mW/cm^2 if P is stated in milliwatts and L is the wavelength in centimeters. In the present situation $P = 1.2 \times 10^9$ mW; using this value and dividing by $(30.48)^2 = 929$ to convert from centimeters to feet yields

$$U_o = 4.0 \times 10^5/L^2 \quad . \tag{8}$$

This value is used as representative of the maximum power density existing within the roughly rectangular near-field column.

B.3.2.2 The Near-Field Extent

Equations (2) and (8) apply to different regions. They give equal values at a particular distance R_o, where

$$U_o = U_1 = 4.0 \times 10^5/L^2 = 16.5 \times 10^6/R_o^2 \tag{9}$$

which yields

$$R_o^2 = 41.25\ L^2 \text{ or } R_o = 6.42\ L \quad . \tag{10}$$

Because $D \simeq 6L$, the ratio D^2/L is given by

$$D^2/L = 36L \quad . \tag{11}$$

Thus

$$R_o = 0.18\ D^2/L \quad . \tag{12}$$

This value is used as a convenient outer limit of the near-field region. Equations (8) and (10) were used to prepare Table B-2, which shows the extent and power densities of the near-field regions of the six arrays.

Table B-2

NEAR-FIELD DISTANCES AND POWER DENSITIES FOR OTH-B ARRAYS

Band	Wavelength, L (ft)	Distance, R_o (ft)	U_o (mW/cm^2)	R_1 (ft)
A	170	1,091	13.84	1,020
B	126	809	25.2	756
C	93.3	599	46.0	560
D	69.3	445	83.3	416
E	51.4	330	152	308
F	39.4	253	258	236

Key:
- U_o = Maximum power density in near-field column
- R_o = End of near-field region
- $R_1 = D \simeq 6L$

B.3.2.3 Average Power Density

Consistent with the width of the array, the near-field column is quite wide and does not move much as the beam is stepped from side to side. Therefore, near the face of the array, the average power density is only slightly affected by beam motion. However, the average value throughout this region is only one-fourth of U_o. The effect of beam motion increases with increase of the distance from the array center (see Figure B-2). At the distance $R_1 = D$, the length of the arc swept by the beam is approximately twice the length of the array; hence, at this distance the average power density is reduced by half from $U_0/4$ to $U_0/8$. Because this value does not differ significantly from the value $U_2 = 0.14\ U_1$ at the same distance, it is legitimate to use U_2 to represent the average power density for all distances greater than R_1 (which does not differ substantially from R_o). At smaller distances, the average power density becomes irregular with local "hot spots" having values as high as U_o. In the charts described in Section B.6, this effect is accounted for by using U_2 down to the distance at which its value is equal to U_o.

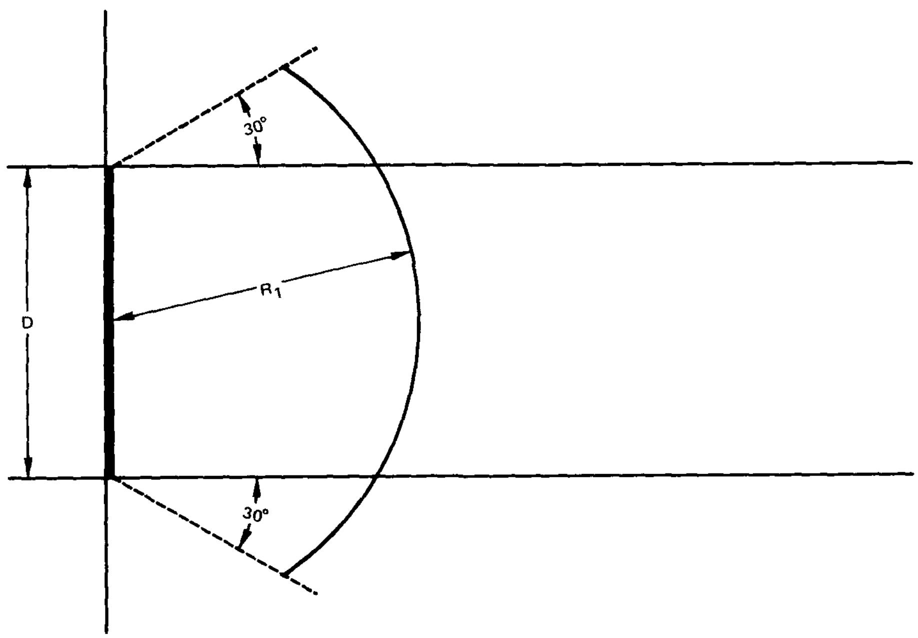

FIGURE B-2 VARIATION OF AVERAGE POWER WITH DISTANCE

B.3.2.4 Effect of the Earth

When a radio wave traveling in air strikes another material such as metal or soil, part of the energy is reflected and part is transmitted into the material. Metals are good reflectors, but soil accepts a substantial fraction of the incident energy. The nature of the wave in the soil and the distance that it penetrates depend on the frequency and the properties of the soil. The behavior of the wave is governed by the ratio of the conductivity S_g* to the product $2\pi fK$, where f is the frequency and K is the (absolute) dielectric constant. For soils in the vicinity of the CRS transmit arrays, the conductivity is the dominant parameter, and the value of dielectric constant is unimportant. Under these conditions, the wave within the soil travels by diffusion rather than propagation, and the dielectric constant is not important. The key parameter is the skin depth, which is the distance penetrated by the wave before its intensity falls to 1/e = 0.37 of its initial value. This distance J is given by Ramo and Whinnery (1953) as where

$$J = (\pi f \mu S_g)^{-1/2} \text{ meters} \tag{13}$$

μ is the magnetic permeability (about 1.26×10^{-6} henry per meter (H/m)). For applicable values of soil conductivity, the value of J is approximately one meter. The essential fact is that the earth will absorb and dissipate power from electromagnetic waves that are propagated over or near its surface.

Because the ground is not a perfect conductor (i.e., reflector), it absorbs power and reduces the intensity of electromagnetic waves near its surface. For the far-field distances of interest, the effect of ground attenuation is to add a term of the form R^4 in the denominator of the equation that relates power density to distance. The coefficient that multiplies R^4 determines the distance at which the variation of power density versus distance makes a transition from $1/R^2$ to $1/R^4$; the transition distance varies with the conductivity of the soil and the frequency used. In the present case it is always larger than 750 ft because of the groundscreen.

A complete analysis of the propagation of radio waves near the surface of the ground is complicated (Norton, 1941). For present purposes, it is sufficient to determine the transition distance R_2. This is the point at which the dimensionless parameter, called the numerical distance, commonly used in such calculations, has the value 1/2. Equations developed by Norton can be combined to yield

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*The unit of conductance, formerly called the mho, is now the siemen. For comparison, the conductivity of sea water is about 4, and the conductivity of copper is 58,000,000.

$$R_2 = 2.9\ L^2\ S_g \tag{14}$$

where L is the wavelength in feet, S_g is the conductivity of the soil, and R_2 is the distance in feet at which the transition occurs. Applicable values for the dielectric constant and conductivity of "marsh land or rice paddies" are taken from a publication of NOSC (D.B. Sailors et al, 1983). Their results are expressed by the equations

$$S_g = 0.1115\ F^{0.106} \quad \text{and} \quad K = 9.76 \times 10^{-10}\ F^{-0.417} \tag{15}$$

where F is the frequency in MHz, and K is the absolute dielectric constant. Values of dielectric constant, conductivity, and skin depth were calculated from these equations and equation (14) and used to develop the set of values presented in Table B-3.

Table B-3

NUMERICAL DISTANCES AND OTHER VALUES FOR OTH-B ARRAYS

Band	A	B	C	D	E	F
F (MHz)	5.81	7.83	10.55	14.22	19.16	24.96
L (ft)	[illegible]70	126	93.3	69.3	51.4	39.4
S_g (s/m)	0.1[illegible]	0.139	0.143	0.148	0.152	0.157
R_2 (ft)	1[illegible],2[illegible]	6,400	3,620	2,060	1,160	700
R_3 (ft)	11,980	7,150	4,360	2,810	1,910	1,450
K (10^{-10}f/m)	4.68	4.14	3.65	3.22	2.84	2.55
J (m)	0.57	0.48	0.41	0.35	0.29	0.25
$2\pi fk/S_g$	0.13	0.15	0.17	0.19	0.22	0.25

In this table, R_2 is the range at which the "numerical distance" = 1/2, and R_3 is the distance (which is 750 ft greater than R_2) at which $1/R^4$ propagation begins. This increment represents the width of the groundscreen, which prevents main beam absorption. The final line of Table B-3 shows that the ratio $2\pi fK/S_g$ is always smaller than unity. This fact justifies the use of equation (14).

Ground-level power densities are further affected by the orientation of the dipole array elements. Bands E and F use the vertical orientation, to which the statements in the preceding paragraph directly apply. However, the elements of the other bands are oriented at 45° from the vertical. In effect, half the total power can be considered to be radiated with vertical polarization and half with horizontal polarization. The horizontal component is effectively suppressed at ground level because of the conducting groundscreen and earth (Norton, 1941). Hence, for bands A, B, C, and D, the ground-level power density is further reduced by 50% at all distances of interest.

With these considerations and the free space power density expressions, the maximum power densities at ground level in sector A can be calculated.

B.3.2.5 Effect of Vegetation

It is known that tropical jungles produce strong attenuation of signals in the 5- to 28-MHz band, and a considerable amount of data exists for jungle propagation. No data directly applicable to the present situation have been found. The following paragraphs develop a basis for estimating the effect of trees or brush that may be found in the vicinity of the CRS transmit arrays.

We proceed by considering a 1 m^2 portion of a vertically polarized electromagnetic wave traveling along the surface of the earth at a frequency f corresponding to a wavelength L. The effect of vegetation is accounted for by considering the region to have a modified (complex) dielectric constant $K = K' + jK''$, where $j = (-1)^{1/2}$ (Ramo and Whinnery, 1953).

For a wave propagating along the surface under these conditions, the attenuation N (in nepers* per meter) is given by the equation

$$N = \pi K''/LK' \quad . \tag{16}$$

The ratio K''/K' is commonly called the loss tangent of the material; in the present situation, it is given by the equation

$$K''/K' = S_b/2\pi f K_o = L\ S_b/2\pi C K_o \tag{17}$$

where S_b is the effective conductivity of the air/vegetation mix, f is the frequency (in Hz), $C = 3 \times 10^8$ is the velocity of light, and $K_o = 8.8 \times 10^{-12}$ is the dielectric constant of free space.

For typical forest environments, the value of S_b is about 10^{-4} (Tamir, 1967). A value of $S_b = 10^{-5}$ is chosen here as representative of the more sparse vegetation typical of the region of the CRS transmit arrays. Use of this number with equations (16) and (17) yields $N = 0.0019$ Np/m, which is independent of frequency.

It is instructive to compare this value with the attenuation caused by imperfect soil conductivity. A convenient formula (Ramo and Whinnery, 1953) is $N = R_s/757$, where $R_s = (\pi f \mu / S_g)^{1/2}$ is the surface resistance of the earth. In this expression, $\mu = 1.26 \times 10^{-6}$ H/m is the magnetic permeability of free space and S_g is the soil conductivity. This expression applies to a plane parallel wave guide system

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*One neper (Np) corresponds to a reduction of the electric field intensity by a ratio of 2.718, or 8.68 dB.

1-m high in which the upper conductor is perfect, whereas the lower conductor has the finite conductivity S_g. Substitution of f = 10.55 MHz and S_g = 0.059 S/m in this equation yields N = 0.035 Np/m.

The important conclusion to be drawn from the foregoing comparison is that, for typically conducting soil, the attenuation due to the earth is large compared with that produced by a credible distribution of vegetation. Thus, attenuation caused by vegetation can be dismissed from further consideration. This statement is based on the assumption that no large trees will be tolerated within the limits of the exclusion fence, described in Section B.7.

B.3.2.6 Beam Overlap

The beam of each array is stepped through a total angle slightly less than ±30° in such a way that the average power density, U_2, remains substantially constant across the boundaries ±30° from the boresight of each array. If the four antenna arrays are configured as a hollow hexagon, no beam overlap occurs. Therefore, both at ground level and throughout the surveillance zone, maximum and time-averaged power densities are essentially constant over the full 240° angular range. If the four antenna arrays are grouped in a configuration so that substantial beam overlap occurs in the region close to the antenna faces, the overlapping beams do not interact, but the average power density in this region is enhanced.

B.4 Sector B

On each side of the sector scanned by the main beam, one sector is exposed only to sidelobes. For each array these sectors are bounded by the values Z = ±30° and Z = ±90°. The levels of RFR in these sectors are substantially lower than those in sector A. A procedure for calculating these levels is developed in the paragraphs that follow. As noted in the following section, the power densities in the range Z = ±50° to Z = ±90° do not exceed those in sector C. Therefore, these regions are merged into sector C.

B.4.1 The Sidelobes--Maximum Power Density

The power densities in the main beam and sidelobes of a uniform 12-element subarray with uniform amplitude and phase are shown in Figure B-3 (Silver, 1949). The maximum intensity of the first (right and left) sidelobes is about 1/20 and the maximum intensity of the most remote sidelobes is about 1/150 that of the main beam. For consistency with the backlobe level specified in Appendix A, we use 1/100 as the lower limit for all sidelobes.

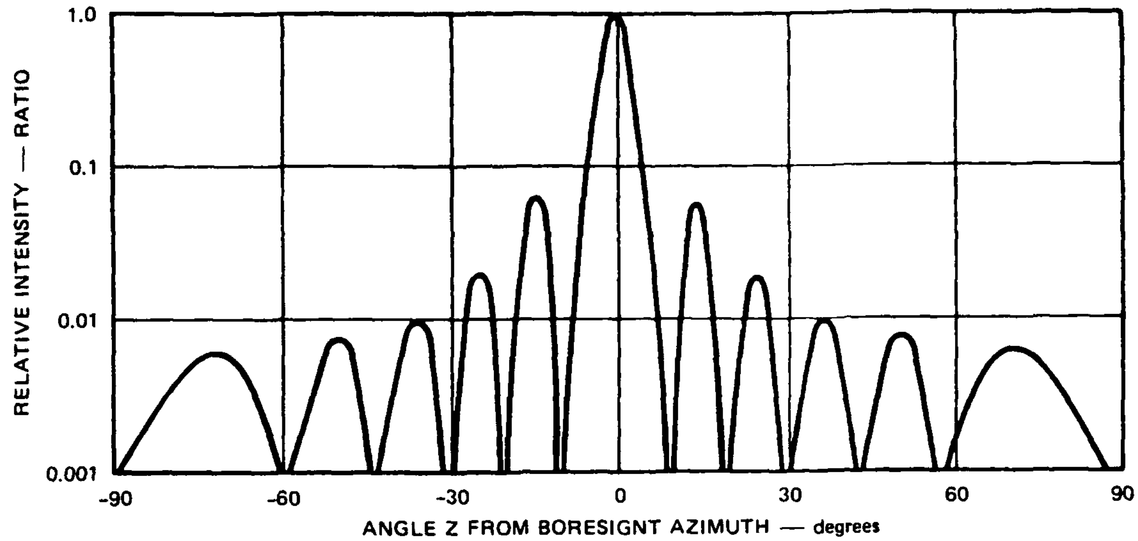

FIGURE B-3 FAR-FIELD PATTERN FOR 12-ELEMENT ARRAY

During the normal beam stepping process, the main beam deviates about ±30° from its boresight position. The first sidelobes follow most of the motion, but the more remote sidelobes are less mobile. Figure B-4 shows the approximate form of the far-field pattern when the beam is deflected through the maximum scan angle of 30°. Only the first and second sidelobes are found in the region 30° to 50°, and their maximum values are well approximated by the sloping straight line shown. As previously noted, the value 0.01, corresponding to 1/100 of the maximum value, is used in the 50° to 90° region.

The foregoing procedure is strictly valid only for the far field. However, the sidelobes do not benefit from the full area of the aperture, and the far-field criterion is satisfied at much smaller distances than for the main beam. Therefore, in the charts shown in Section B.6, the $1/R^2$ segment is continued down to R = 100 ft.

B.4.2 <u>The Sidelobes--Average Power Density</u>

The beam-stepping process, which produces a continual motion of the sidelobes as well as of the main beam, causes the average power density in the B sectors to be lower than the maximum density. Consistent with the values used in sectors A and C, this reduction factor is taken as 0.14. The validity of this value is clarified in Section B.5.2.

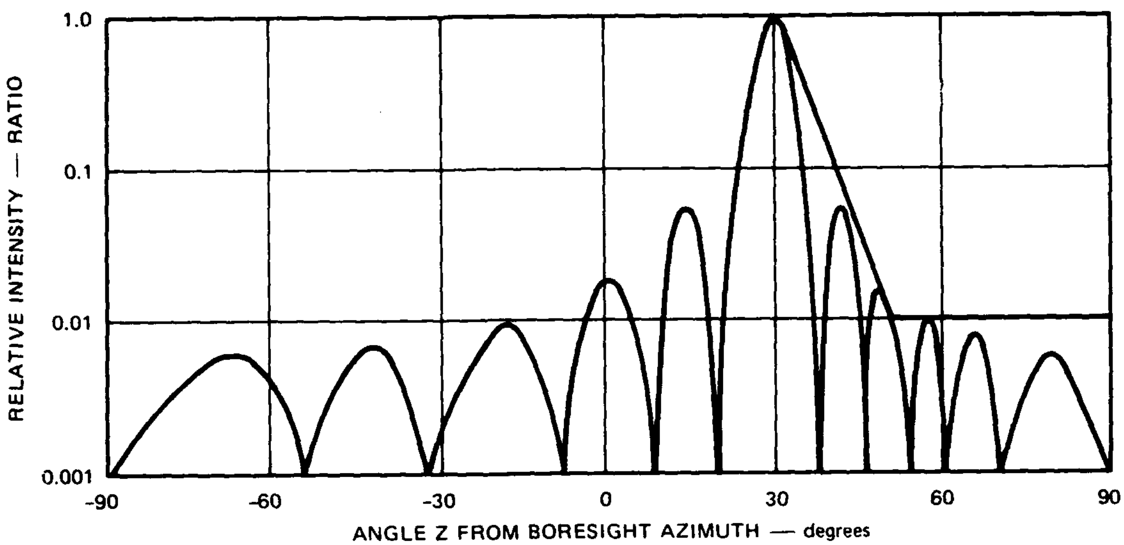

FIGURE B-4 FAR-FIELD PATTERN FOR 12-ELEMENT ARRAY — AT SCAN LIMIT

B.5 Sector C

B.5.1 Maximum Power Density

Sector C is the region where Z is greater than 90°, corresponding to locations entirely behind the backscreen. As noted in Table A-3, the maximum intensity in this sector is never greater than 1/100 that in the center of the main beam. Moreover, there is no groundscreen to reduce ground losses near the antenna. This information is sufficient for calculating maximum power densities throughout sector C.

B.5.2 Average Power Density

The distribution of power in sector C is nonuniform and changes with the scan angle of the various beams. Thus, average power densities are considerably lower than corresponding maximum values. Numerous measurements of the backlobe distribution of reflector-type antennas (Katz, 1979) indicate that such antennas have values of median absolute gain near -10 dB, that is, about 0.1. As noted in Appendix A, the maximum value of absolute gain in sector C is +2dB, or 1.6. Application of these values to the present situation would lead to a factor of 16 as the ratio of maximum to average power densities in sector C. To be conservative, and for consistency with sector A, we use the smaller factor 7 (or its reciprocal 0.14) to relate peak and average power densities in sectors B and C.

B.6 Preparation of the Charts

The preceding sections have developed expressions for calculating maximum and average power densities generated by the individual arrays. These results are now combined to describe the total radiation produced by all the subarrays of any single complete antenna array. The various sectors are identified in Figure B-1, with the understanding that the extent of sector B is reduced from 60° to 20°.

In the far field of sector A, the maximum and average power densities are both uniform for all values of Z less than 30°. In the B sectors, both maximum and average power densities in the far field decrease in an orderly manner as Z increases from 30° to 50°, at which point they become independent of Z and have magnitudes that are 100 times smaller than those in sector A.

B.6.1 Chart for Band F

The procedure used is illustrated in Figure B-5 for band F, which uses vertical dipoles. Reference to Table B-2 yields U_o = 258 mW/cm^2 and R_o = 253 ft. Starting at this point, a horizontal line is drawn to the left; it represents the maximum power density in the near-field column of the main beam. A line with a slope corresponding to $1/R^2$ is drawn to the right. At $R = R_3$ = 1,070 ft (taken from Table B-3), the sloping line branches. The continuing dotted segment represents the maximum power density in the elevated main beam. The dashed line starting down from R_3 = 1,070 ft represents maximum power density at ground level for S_g = 0.071 S/m; its slope corresponds to $1/R^4$ variation with distance.

Average power density is represented by solid lines parallel to those just identified. The separation represents a relative magnitude of 0.14. The upper line is continued to the left until it intersects the horizontal line that represents U_o. This intersection occurs near R = 100 ft. This construction completes the treatment of sector A.

We next turn to sector C, which corresponds to values of Z greater than 50° relative to the applicable face. The backlobes that represent RFR in sector C have a maximum intensity that is 1/100 that of the main beam and vary with time.

The conditions in sector C differ from those in sector A in two important respects: (1) there is no groundscreen; therefore, branching occurs at R_2 = 320 ft instead of R_3 = 1,070 ft, and (2) there is no orderly near-field column; therefore, the dashed line for maximum power density does not break at R_o = 253 ft. The lines representing average power density in sector C are parallel to those representing maximum power density and have a relative magnitude of 0.14.

Sector B corresponds to values of relative Z between 30° and 50°. Values of RFR in the B sectors are obtained by linear interpolation

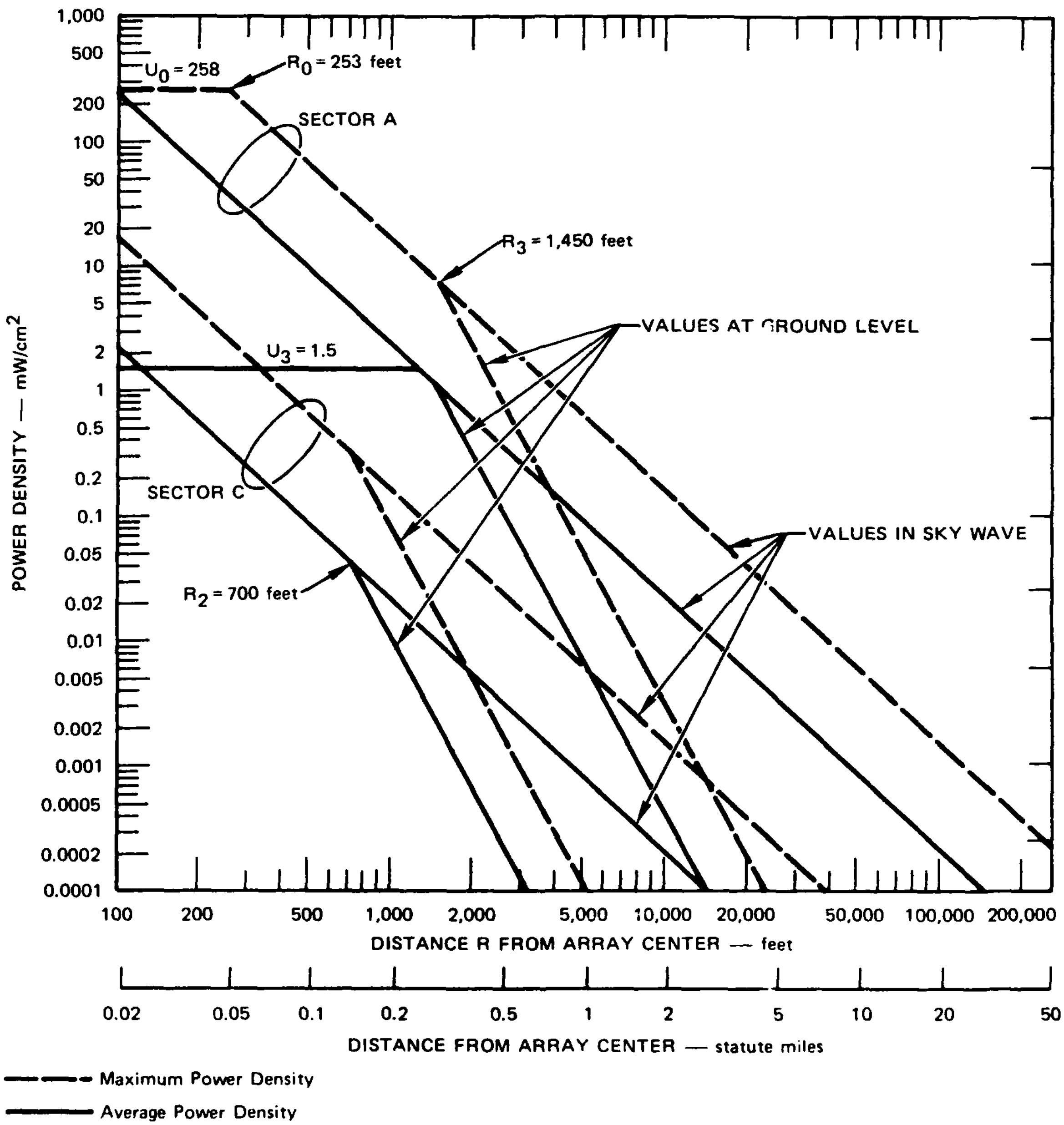

FIGURE B-5 RFR VALUES FOR BAND F

between those for sector A and sector C. For example, the maximum power density at an azimuth of 35° is found one-fourth of the way from the maximum power density line for sector A and that for sector C. A similar statement applies to the average power density in this sector. Linear interpolation (on logarithmic paper) is chosen because it is believed to give an accurate estimate of real-world values of RFR. This completes the construction of Figure B-5. Figure B-6 for Band E follows exactly the same procedure, the only differences being the numerical values of U_o, R_o, R_2 and R_3.

Bands A, B, C, and D use dipoles that are inclined at an angle of 45°; such dipoles radiate half their power with horizontal polarization. Only vertical polarization is sustained near a conducting surface such as that of the earth. Therefore, ground-level values of RFR--both maximum and average--are half as large as they would be if the dipoles were vertical. Figures B-7 through B-10 were prepared on this basis.

Figures B-5 through B-10 give RFR values directly for the soil conductivity values shown in Table B-3. Lower values of power density will exist whenever the conductivity values are lower.

B.6.2 Electric Field Intensities

For assessing hazards to electroexplosive devices (EEDs) and cardiac pacemakers, the electric field intensity corresponding to a given power density is needed. The electric field intensity E, given in V/m, may be calculated from:

$$E = (3{,}770\ U)^{1/2} \qquad (18)$$

where U is the power density in mW/cm^2.

This relationship* is used to establish the scale along the right-hand edge of Figures B-5 through B-10. It is designated E_m to emphasize that it is applicable only to maximum values of intensity because average values of electric field have little significance.

B.7 Estimating Safe Distances

The most recent ANSI standard (ANSI, 1982) specifies power density limits that vary from 1.0 mW/cm^2 at 30 MHz to 36 mW/cm^2 at 5 MHz+. The applicable equation is

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*This relationship is exact only in the sky wave, but it is a good approximation for all conditions of this EIS.

+The ANSI standard calls for time averaging over an interval not exceeding 6 min. This condition is met for all scan sequences of the OTH-B radar.

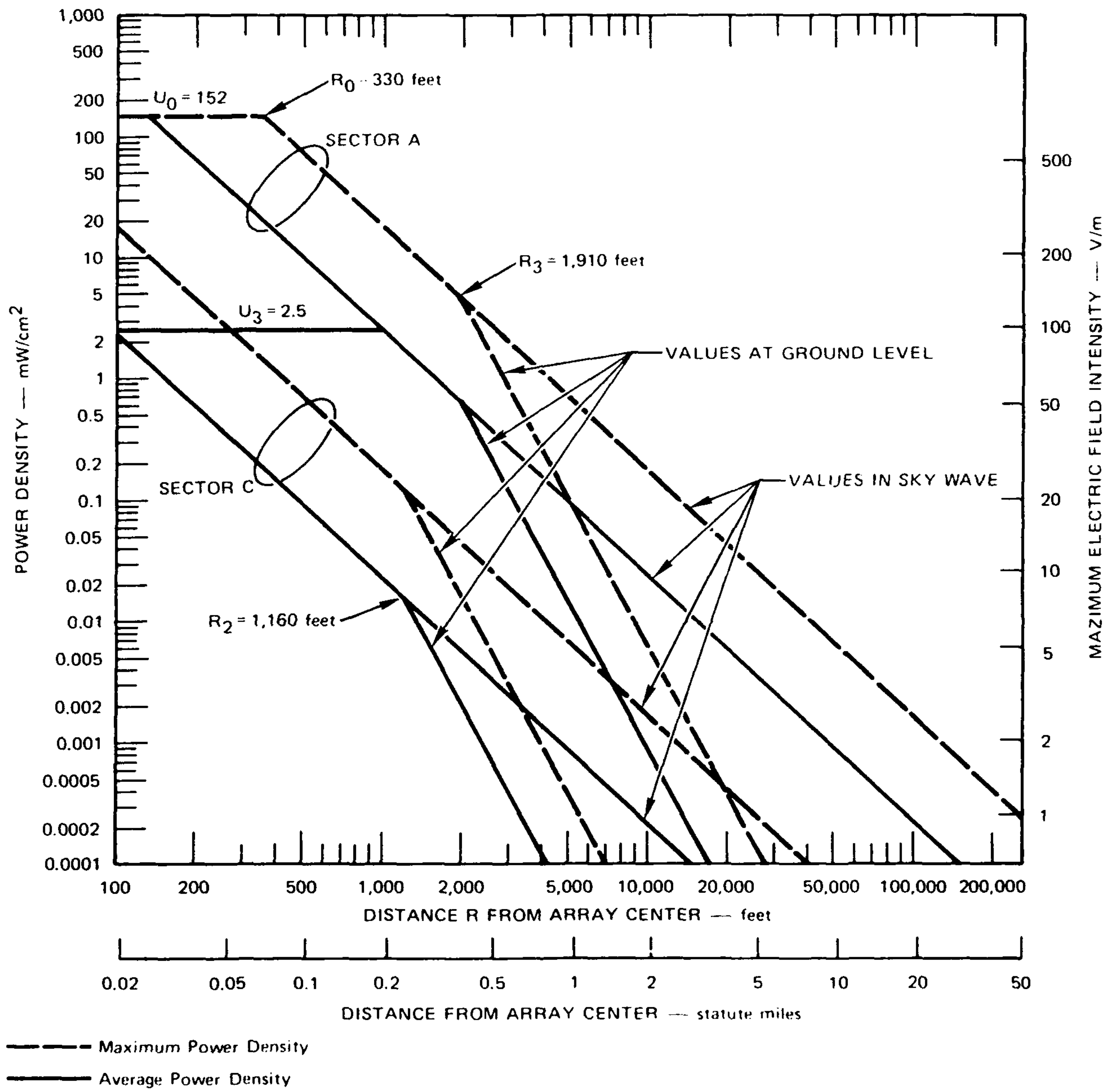


FIGURE B-6 RFR VALUES FOR BAND E

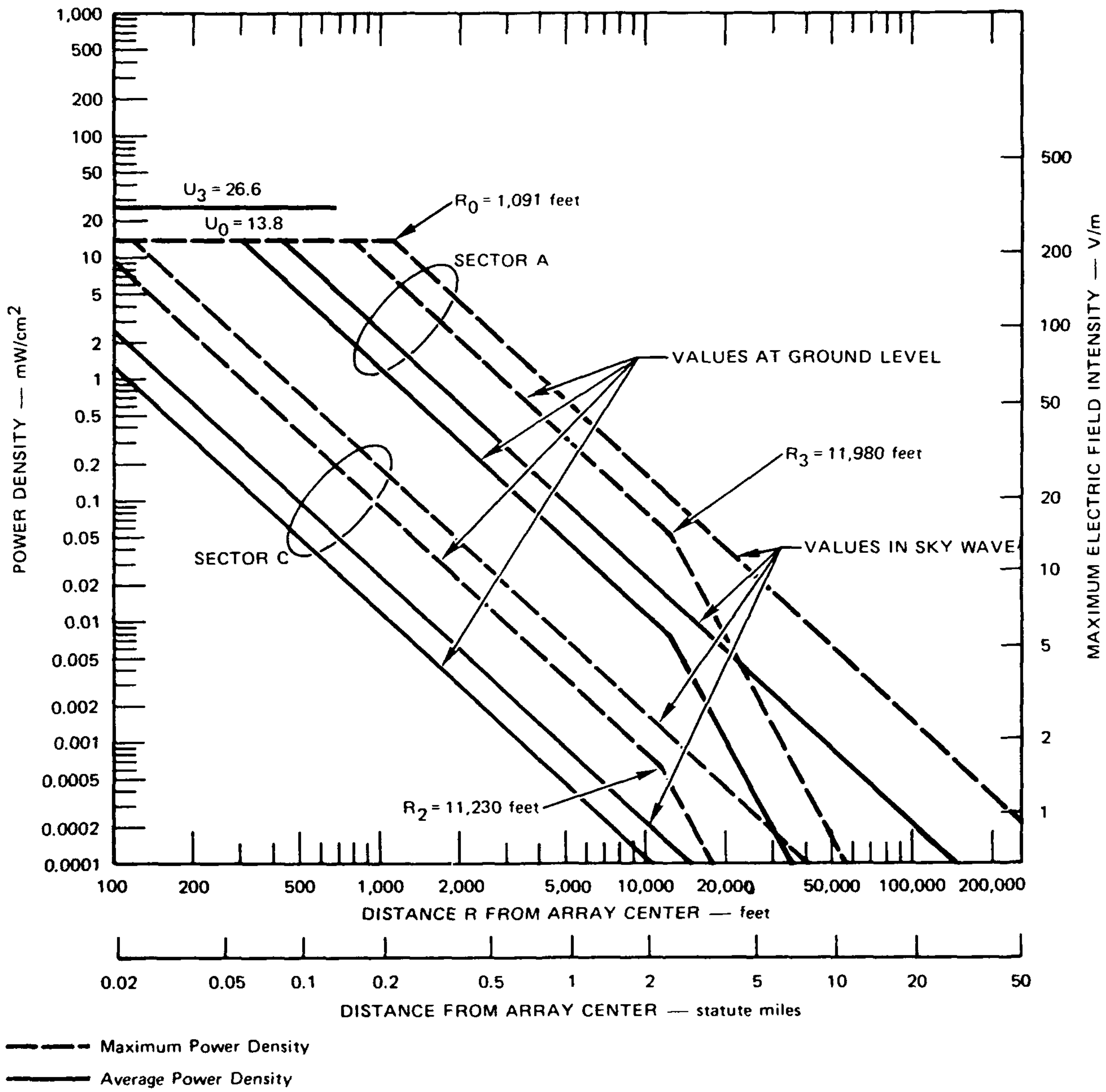


FIGURE B-7 RFR VALUES FOR BAND A

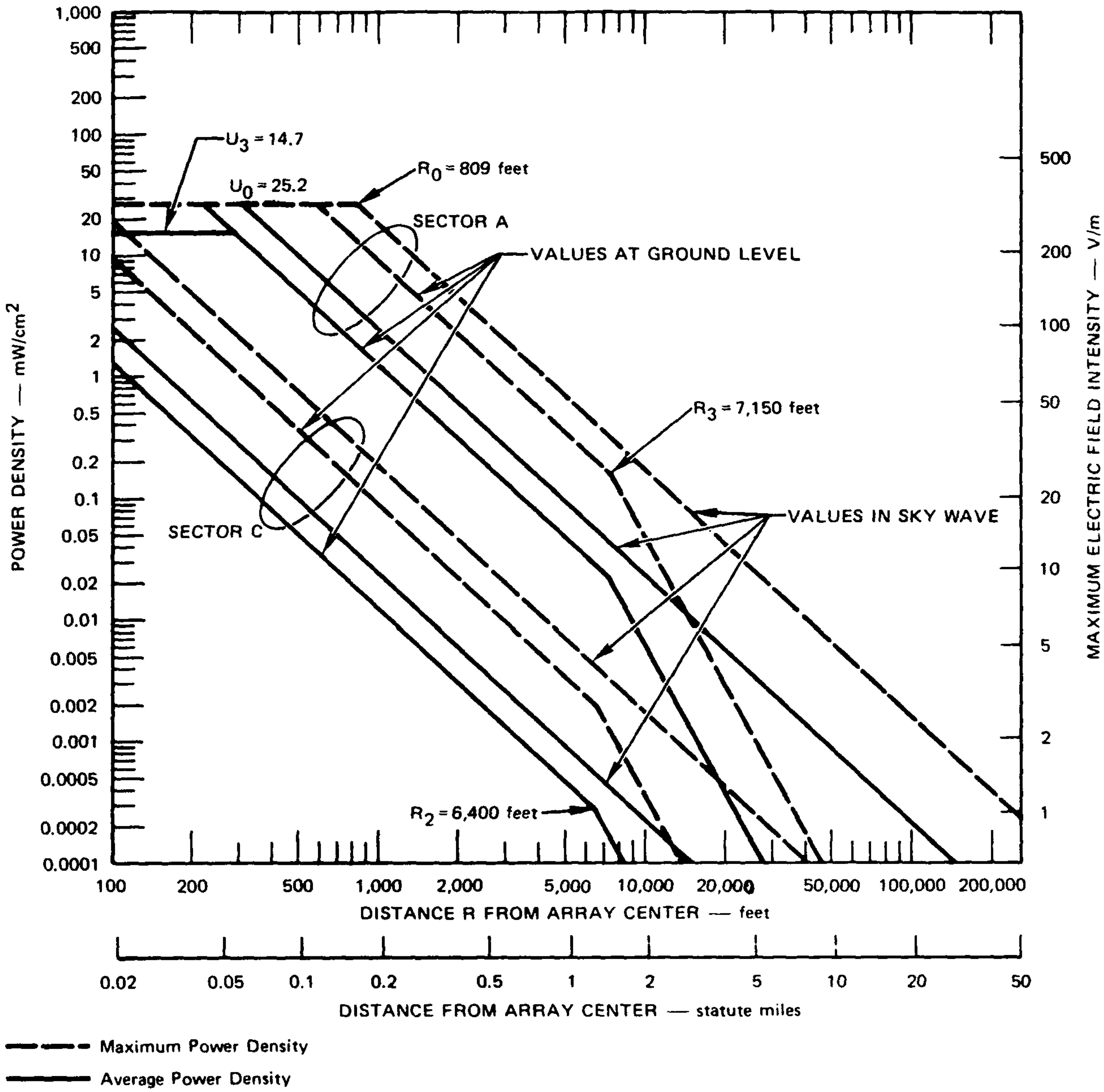


FIGURE B-8 RFR VALUES FOR BAND B

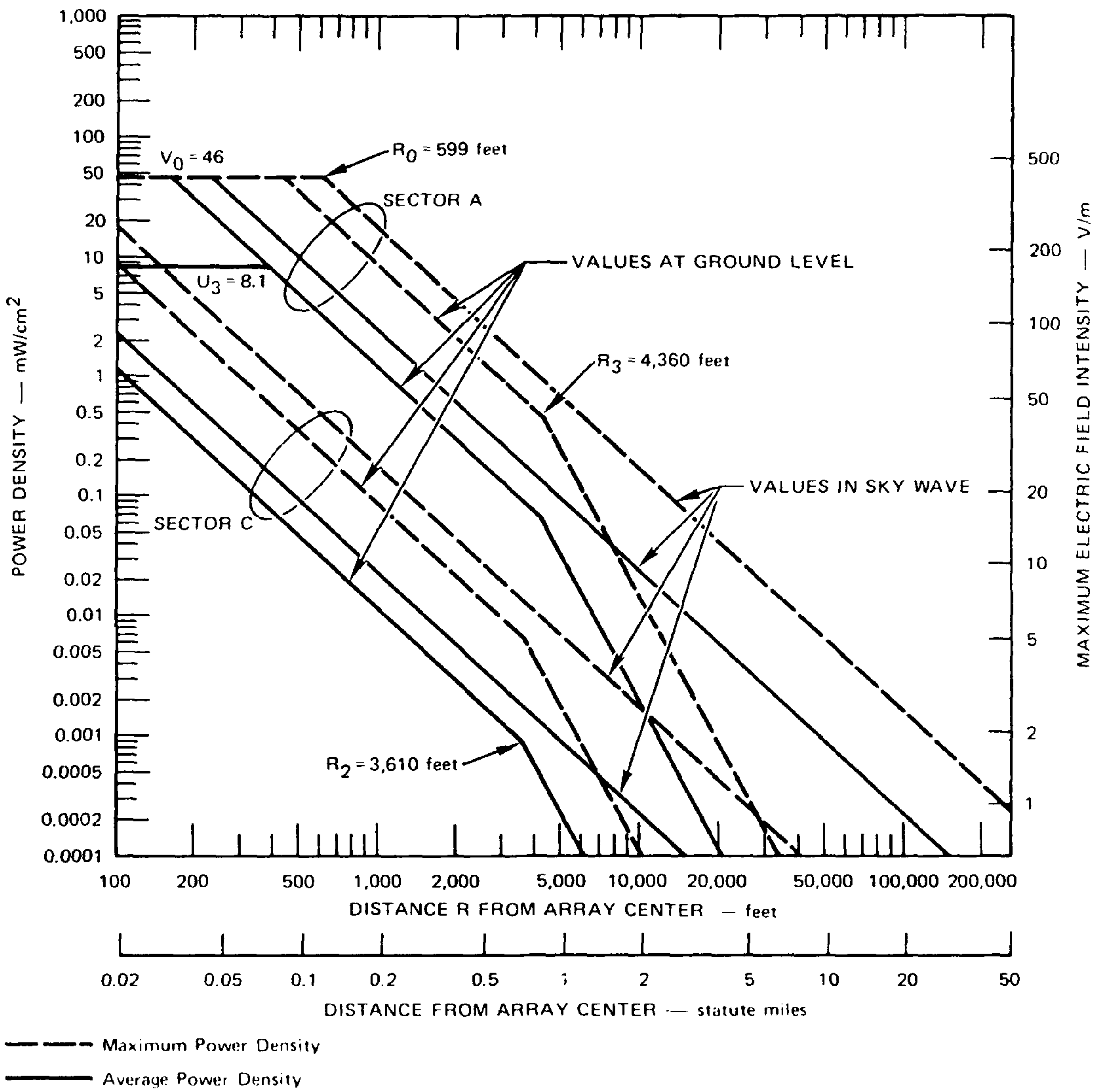


FIGURE B-9 RFR VALUES FOR BAND C

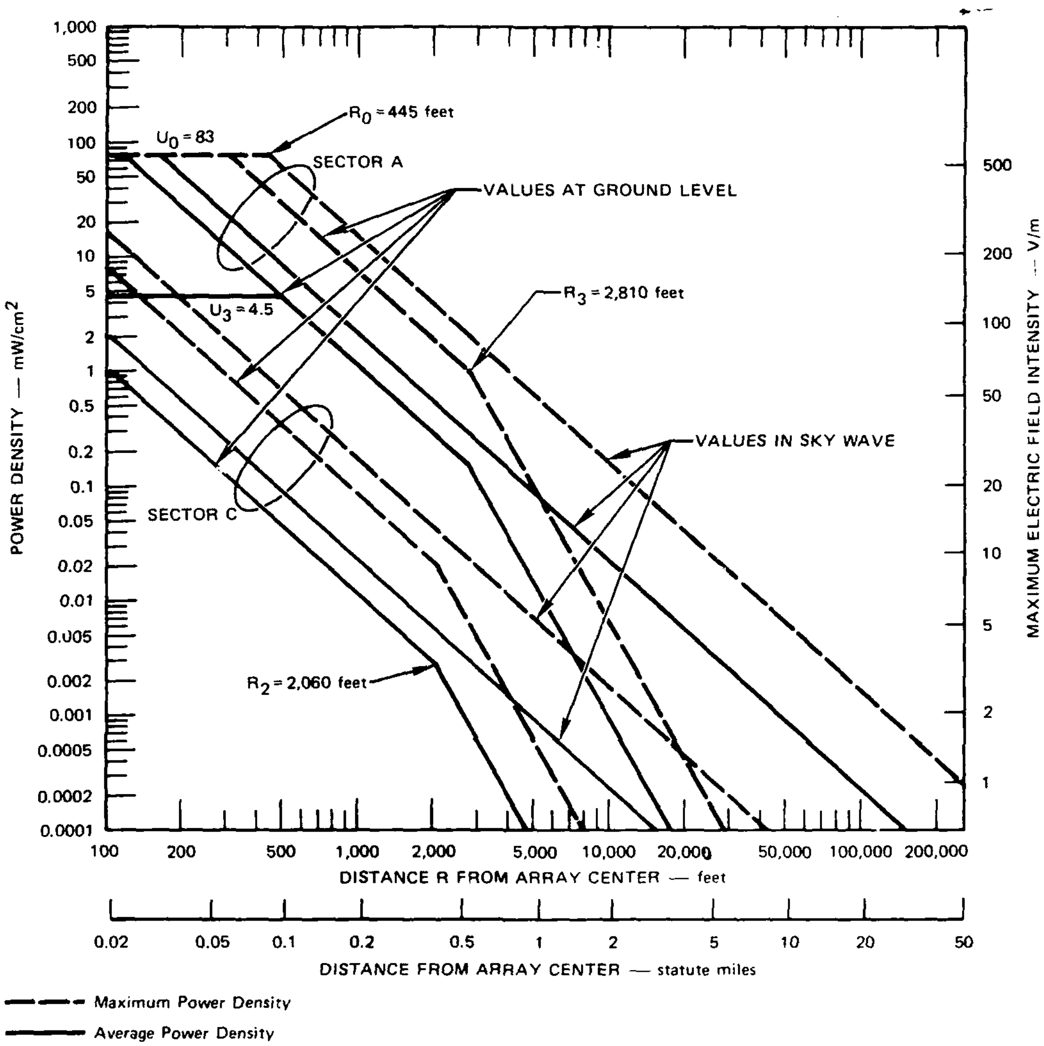


FIGURE B-10 RFR VALUES FOR BAND D

$$U_3 = 900/F^2 \quad (19)$$

Values calculated from this equation for the mid-band frequency of each array are presented in Table B-4 and shown as horizontal lines in Figures B-5 through B-10. The intersections of these lines with the sloping average-power lines give the safe-distance values presented in Table B-4.

Table B-4

SAFE DISTANCES FOR OTH-B ARRAYS

	Band					
	A	B	C	D	E	F
$U = 900/F^2$	26.6	14.7	8.1	4.5	2.5	1.5
Sector A, ft		270	370	500	950	1,250
Sector C, ft		27	37	50	95	125

B.8 Validation

The validity of the methods used to derive the results presented in Figures B-5 through B-10 has been confirmed by comparing the results of similar calculations with measurements made on 9-10 June 1981, at the ERS transmitter site near Moscow, Maine, which included only a single antenna array with four transmitting subarrays. Because the ERS operated below the 1.2-MW power level of the proposed CRS, the measurements have been scaled up to indicate the levels that would have existed if the transmit power had been 1.2 MW. Only bands B, C, D, and E were operational and available for measurement.

The measurement locations are indicated by numbers 1 through 14 on Figure B-11. Positions 1 through 4 were about 10 to 15 ft inside the exclusion fence and about 2,400 ft in front of the antenna array centers for bands C, E, D, and B, respectively. Positions 5 through 8 were all about 5 to 10 ft outside the exclusion fence and alongside the access road. Position 9 was about 20 ft outside the fence and 3 ft in front of the plane of the backscreen; it was therefore behind the dipole elements of the array. Position 10 was at the same distance outside the fence, but situated in the same plane as the band-B dipole elements. Positions 11 through 14 were behind the centers of the antenna arrays about 5 ft outside the exclusion fence. For those points, the approximate distances from the backscreen were 110 ft for band B, 115 ft for band D, 40 ft for band E, and 115 ft for band C.

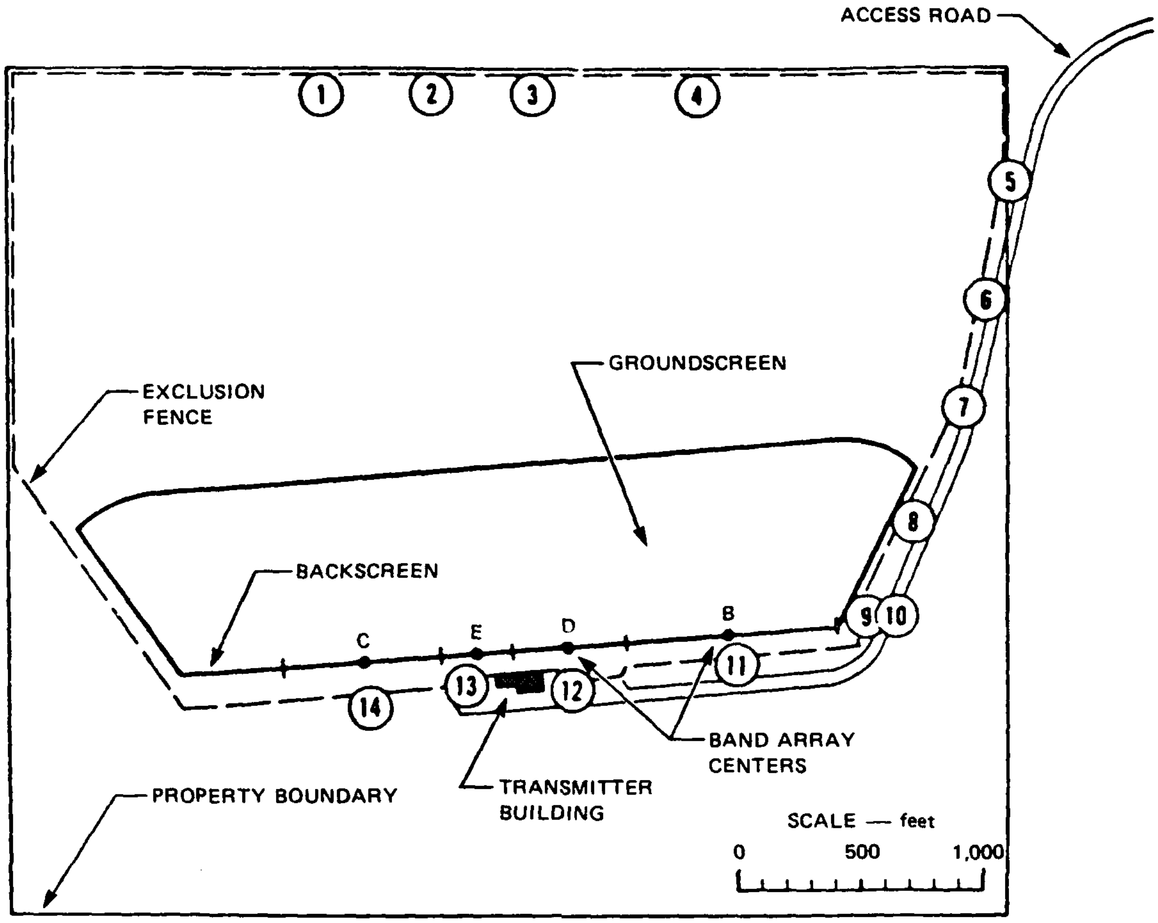


FIGURE B-11 MEASUREMENT LOCATIONS AT THE ERS TRANSMITTER SITE

Four transmitted frequencies were used--one near the center of each of the four bands. They were 7.83 MHz for band B, 10.55 MHz for band C, 14.54 MHz for band D, and 19.20 MHz for band E. The radar was operated in a CW mode at these fixed frequencies, instead of its usual FM mode. This procedure facilitated the accurate tuning of the measurement equipment while leaving the power density unaffected. The azimuth of the beam was stepped in increments of 4°; it was not swept continuously. Thus, the power density measurements correspond to maximum rather than average values.

B.8.1 Measurement Equipment

The measurement receiver was a Singer Model NM-26T Electromagnetic Noise Meter operating as a calibrated, tuned radiofrequency voltmeter. This battery-operated receiver has a bandwidth of about 3.6 kHz and is tunable over the range from 150 kHz to 32 MHz. It has an internal impulse generator for calibration at the frequency of measurement. Its rms detector was used so that true rms signal-level values were obtained.

The antenna was a Singer Model 92200-3 loop antenna, which includes its own matching network. The antenna, mounted on a wooden tripod at a height of about 4.5 ft, was connected to the receiver by a 6-ft length of RG-58/U flexible coaxial cable. Although such a loop antenna senses the magnetic field, the manufacturer's calibration curves allow the antenna's output voltage to be interpreted as the equivalent electric field anywhere within the far field of the source. Power density may be calculated from the electric and magnetic field strengths.

Communication between the measurement team and the operators of the radar was maintained by VHF handy-talkies.

B.8.2 Measurement Procedures

At each measurement location, the equipment was set up, and communication was established with the radar operators to tell them the desired frequency and beam-azimuth angle. The receiver was tuned to the appropriate frequency, which was verified by having the transmitter turned off and on. The loop antenna was then oriented for the maximum signal level. In most cases it was found that the maximum signal was received with the plane of the loop vertical and intersecting the midpoint of the antenna array; exceptions are discussed later. In this orientation, the horizontal magnetic field (vertical electric field) can be measured. Measurements were also made with the plane of the loop horizontal to sample the vertical magnetic field (horizontal electric field). A data sheet was used for each location to log details of the location as well as the meter readings and other pertinent data.

At the more remote locations (positions 1 through 4), heavy brush and sloping terrain made it difficult for the measurement team to determine when they were directly in front of the operating antenna arrays. To ensure that maximum power density was measured, the beam was deviated $\pm 16°$ in azimuth in increments of 4°.

At positions 5 through 8, only band B was measured, and the beam azimuth was stepped from 30° right to 4° left while measurements were made again at 4° intervals.

All four bands were measured at position 9, although the beam was stepped only for the band-B measurements. At position 10, only band B was measured; the beam was steered to 30° right azimuth.

At positions 11 through 14 behind the arrays, the measurements were made with the associated transmitting antenna beams undeviated. The loop was oriented to maximize the level of the received signal.

The ground in the vicinity of the radar was very wet during the measurements, maximizing the soil conductivity and, hence, the values of power density near the ground. At some points, there was standing or running water to a depth of perhaps a foot.

The transmitter system was not operated at the full 1.2-MW output; the actual output power was recorded for each measurement frequency so that the measured signal levels could be adjusted upwards to determine the equivalent 1.2-MW output values.

B.8.3 Results

The horizontal magnetic field (vertical electric field) predominated over the vertical magnetic field by a factor of 100 or more at all measurement points. This implies that essentially all the power density in the field could be determined by measuring the horizontal magnetic field or, equivalently, the corresponding vertical electric field. The meter readings made in the field were converted to power density and then scaled up to the actual transmitter output power. This scaling factor was determined by the radar crew; because it varied with frequency, a different factor was needed for each of the four measurement frequencies.

Table B-5 shows the measured (and scaled) power density figures and the corresponding calculated values. At positions 1 through 4, distinct beam maxima were found as the beam direction was varied; those maxima are reported on the table. At positions 5 through 8, the maximum was found when the band B beam was steered its full 30° to the right; those values are the ones reported on the table. At position 9, measurements were attempted from all four arrays. However, the levels from bands E and C were very low; those arrays presumably produced a deep null in the direction of position 9. Band D also provided a low level there; the level reported in the table was measured with the beam pointed 30° right. The level from the band B array fluctuated only slightly as the beam direction was varied. At position 10 only band B was measured, and the beam direction was 30° right azimuth.

Although positions 11 through 14 are all directly behind their respective array centers (between the sixth and seventh elements), the maximum power density was not generally found by directing the loop antenna at the array center. Viewed from behind, the elements of bands D and C are tilted 45° clockwise, those of band B are tilted 45° counterclockwise, and only the elements of the band E array are vertical. Thus, in the clockwise-tilted arrays, the dipole elements to the right of the measuring point appear foreshortened so that they are directing less than their full strength at the measuring position; however, because those elements to the left are viewed in essentially their full length, they direct a greater amount of power toward the measurement position. It was confirmed at all four behind-the-array points that the maximum power came from the described direction. Consistent with the fact that the band E elements are not tilted, the maximum power at position 13 was found with the measurement antenna directed at the array center.

Table B-5

COMPARISON OF MEASURED AND CALCULATED POWER DENSITIES FOR THE ERS TRANSMITTER

Measurement Position[a]	Sector	Relative Azimuth, Z (degrees)	Distance, R (ft)	Band	Frequency (MHz)	Power Density (mW/cm^2) Measured (and Scaled)	Power Density (mW/cm^2) Calculated
1	A	0	2,400	C	10.54	0.035	0.22
2	A	0	2,400	E	19.20	0.16	0.34
3	A	0	2,400	D	14.54	0.074	0.18
4	A	0	2,400	B	7.83	0.088	0.14
5	B	35	2,400	B	7.83	0.068	0.15
6	B	42	1,800	B	7.83	0.19	0.35
7	C	50	1,300	B	7.83	0.14	0.15
8	C	65	900	B	7.83	0.39	0.19
9	C	90	500	B	7.83	0.081	0.50
9	C	b	1,200	D	14.54	0.0093	0.025
9	C	b	2,000	C	10.54	7.1×10^{-11}	0.005
9	C	b	1,600	E	19.20	2.4×10^{-11}	0.016
10	C	b	500	B	7.83	0.12	0.26
11	C	b	110	B	7.83	0.049	0.26
12	C	b	115	D	14.54	0.076	0.85
13	C	b	40	E	19.20	0.38	1.5
14	C	b	115	C	10.54	0.069	0.46

[a]See Figure B-13.

[b]These sites have azimuth values greater than 90°.

B.9 References

ANSI (American National Standards Institute), "Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 300 kHz to 100 GHz," Report No. C95.1-1982, published by the Institute of Electrical and Electronics Engineers, New York, New York (1982).

Hansen, R. C., Microwave Scanning Antennas, Vol. 1, "Apertures," Academic Press, New York (1964).

Hu, M. K., "Fresnel Region Fields of Circular Aperture Antennas," Journal of Research, National Bureau of Standards, Vol. 65D, No. 2 (March-April 1961).

Katz, L., "Aperture Antenna Hemispheric Gain Statistics," IEEE International Symposium on EMC, San Diego, CA (1979).

Norton, K. A., "The Calculation of Ground-Wave Field Intensity over a Finitely Conducting Spherical Earth," Proc. IRE, Vol. 29, pp. 623-639 (1941).

Ramo, S. and J. R. Whinnery, Fields and Waves in Modern Radio, Second Edition, John Wiley & Sons, Inc., New York (1953).

Sailors, D.B., W.K. Moision, and T.N. Roy, "The New U.S. Army PROPHET Evaluation System (APES) Models," Technical Document 642, Interim Report, Naval Ocean Systems Center, San Diego, CA (December 1983) (Corrected).

Scott, J., General Electric Company, personal communication (November 1982).

Silver, S., "Microwave Antenna Theory and Design," McGraw-Hill Book Company Inc., New York (1949).

Snyder, A. L., "System Specifications for the Over-the-Horizon Backscatter Operational Radar System," U.S. Air Force Electronics Systems Division, Hanscom Air Force Base, MA (3 June 1982).

Stevenson, R. Bruce, The MITRE Corporation, Bedford, MA, personal communication (June 1986).

Tamir, T., "On Radio Wave Propagation in Forest Environments," IEEE Trans. Antennas and Propagation, Vol. AP-15, No. 6 (November 1967).

Appendix C

ELECTROMAGNETIC INTERFERENCE AND HAZARDS TO SYSTEMS

CONTENTS

ILLUSTRATIONS

TABLES

Appendix C

ELECTROMAGNETIC INTERFERENCE AND HAZARDS TO SYSTEMS

C.1 Introduction

This appendix presents an analysis of the potential effects on other systems of the operation of an OTH-B radar system transmit site at any of the study areas identified as potentially suitable. One area is near Aberdeen, South Dakota, and the other three are near Wheaton, Minnesota. The systems considered include those that use the electromagnetic spectrum, as well as others that are not designed to use it but that may be susceptible to the energy radiated by the radar. Systems in the first group include telecommunication and radionavigation systems, all of which are designed to sense electromagnetic energy. Systems in the second group include cardiac pacemakers and electroexplosive devices (EEDs), which may inadvertently be subjected to the radar energy.

Appendix A describes the frequency and time behavior of the radar. Information on the characteristics of the emission is basic to an analysis of the effects of any emitter of electromagnetic fields. An OTH-B radar is a complicated system operating with computer guidance according to preprogrammed operating algorithms and using complex signal processing schemes to extract aircraft tracking information from the backscattered signal. Its beams do not sweep; rather, they probe from one azimuth to another, sometimes in a seemingly random manner. An OTH-B radar has a repertoire of operating bandwidths, and it can switch frequency to illuminate the ocean at different distances and as required by changes in the ionosphere. The operation is not predictable from moment to moment, because the radar's computer may alter the routine barrier scanning operation to provide tracking data on some of the aircraft the radar detects and because the radar operators may decide to abandon a frequency that is experiencing interference. Section C.2 of this appendix discusses the selection of the radar's operating frequency, the radar's emissions, and the propagation of energy by ground wave and sky wave.

Section C.3 analyzes incidental electromagnetic effects of an OTH-B radar. It is divided into two subsections. Section C.3.1 discusses the effects on other telecommunication systems, and Section C.3.2 discusses three inadvertent receivers of energy. In both sections, we first determine whether and how the subject system may be susceptible to the characteristics of the OTH-B signal, and then we attempt to determine the OTH-B signal levels at which the subject system will experience some effect. Having determined those levels, we can estimate the distance from OTH-B at which the effect would occur. Because of the many uncertainties involved in this process, firm predictions are seldom possible.

C.1.1 <u>Background</u>

To determine the likelihood that an emitter of electromagnetic energy will cause electromagnetic interference (EMI) to some other system, some knowledge is required of the operating characteristics of both systems and of the means by which the electromagnetic energy is propagated from one to the other. For example, we must determine the threshold of susceptibility for a system subject to interference--that is, the lowest level of undesired signal that causes some perceptible effect on the susceptible system (or activity). The systems include communication systems and cardiac pacemakers; activities include the handling of volatile fuels and EEDs.

The threshold of susceptibility typically must be determined separately for each pair of interfering system and potentially interfered-with system. This is necessary because the threshold of susceptibility depends not only on the power density of the undesired signal at the potentially susceptible system (and therefore on the distance between them), but also on the frequency of the undesired signal and the characteristics of its modulation. Theory is useful in predicting likely modes of interference and can be of considerable value in predicting thresholds of susceptibility. Measurements, however, are often needed when theory is not sufficient or to confirm the theoretical results. Unfortunately, each new situation is usually unique in some way, and measured susceptibility thresholds applicable to that situation are generally not available.

We can rarely make definitive statements regarding the distances from the radar beyond which a given system will not be affected. Available susceptibility levels are either educated judgments or are based on measurements of only a very few units, generally selected in the hope that they are representative or typical of their type. They could, however, be either more or less susceptible than the entire population of units of that type. The variation in the susceptibility levels of all the units of a type (taken as a group) may be quite large, but is generally unknown. Also, circuit designs change, and the susceptibilities of the systems change with them. The nature of radio-wave propagation is such that the level of the interfering signal will not be the same at all locations at the same distance from the source. At a given location, the level varies with time and so dealing with expected, or median, values is common. This is also true of the desired signals, when they are applicable.

In some situations, attempting to determine actual susceptibility is not necessary because standards for maximum permissible fields have been established; in this case, the devices or systems are said to be safe if that field is not exceeded. Such standards exist for EEDs and for fuel handling, and a draft standard was once developed for cardiac pacemakers.

C.1.2 Scope

C.1.2.1 The OTH-B Transmit System

This appendix will deal solely with the emissions of the OTH-B radar transmit system and with their potential to produce EMI in other electronic systems or to imperil systems or devices not intended to receive electromagnetic fields. All information presented here has been obtained from unclassified sources; no classified material was reviewed during the preparation of this appendix.

C.1.2.2 Auxiliary Transmitting Systems

Although several radio transmitting systems will operate as adjuncts to the OTH-B radar system, the scope of this appendix does not include determining their effects on the electromagnetic environment. Any effects would be slight in comparison. The power levels of the adjuncts are to be much lower, and the other systems would generally remain on assigned frequencies.

C.1.2.2.1 Land Mobile Radio Systems

The Air Force will use VHF or UHF land mobile radio systems at both the transmit and receive sites to support maintenance and security activities in the antenna fields and other areas within the complexes. These will be standard, commercially available transceivers such as those used by police, fire departments, the Forest Service, and other organizations. These vehicle-mounted or hand-carried systems will operate on frequencies assigned by the National Telecommunications and Information Administration (NTIA) through the Interdepartment Radio Advisory Committee so as to avoid interference with other users of the land mobile bands.

C.1.2.2.2 Vertical Incidence and Backscatter Sounding

To aid in determining which frequencies to use, and to monitor the ionosphere overhead, both vertical and oblique incidence sounding will be employed. The sounder system will be able to operate over the frequency range of 2 to 30 MHz, but will not transmit on the distress, calling, and guarded frequencies listed in Table A-1, Appendix A. The effective radiated power will be adjustable from 37 to 47 dBW (factors of approximately 40,000 to 4,000 less than the maximum effective radiated power of the radar itself).

C.1.2.2.3 Data Links

Operational data and instructions for controlling the system will need to be transmitted in real time between and among the transmit site, the receive site, and the operations center. A radio system will be used for this purpose. However, the system has not yet been specified, so its effects cannot be described.

C.2 The OTH-B Signal

C.2.1 Frequencies and Their Selection

C.2.1.1 Available Frequency Bands

The NTIA has authorized the OTH-B radar to operate on a "noninterference" basis within any of about 30 bands between 5 and 28 MHz. These bands, within the high frequency (HF) portion of the radio spectrum, are shared with users of the Fixed and the Broadcast Services. The Fixed Service is intended for point-to-point transfer of information between two cooperating fixed (i.e., not mobile) stations. Although various types of modulation, such as voice or teletype, may be used, Villard (1980) indicates that the HF bands are used less frequently for this purpose than before the introduction of satellite systems, which have numerous advantages over HF systems. The Broadcast Service uses transmitters located throughout the world and operated by private industry, governments, religious organizations, and other groups. Those stations operating in the HF band are most often used for international or tropical broadcasting. Hundreds of these stations, including Voice of America, Radio Moscow, and Radio Havana, broadcast news, music, and other features generally intended for listeners beyond the country of origin.

All other portions of the HF band, including the bands occupied by the Aeronautical Mobile and Maritime Mobile Services, by the Amateur Radio Service (i.e., the Hams), and the Standard Frequencies, are forbidden to the radar. The first two services are used for communication between and among ships, aircraft, and shore or ground stations. The Hams are dedicated hobbyists who communicate with other Hams throughout the world using the HF bands. The Standard Frequency bands support transmission of precise time and frequency information, as well as propagation predictions, solar and geophysical data, and the like. They are operated by national government agencies and include WWV in Colorado, CHU in Ontario, and JJY near Tokyo.

Other special purpose frequencies, such as Search and Rescue Control and similar frequencies, are not to be used by the radar. They are listed in Table A-1, Appendix A.

C.2.1.2 Selection of the Operating Frequency

Under normal operation, each of the four antenna arrays or faces of the CRS radar transmitter system sequentially illuminates its own eight adjacent barrier sectors beyond the horizon. Each of these 32 barrier sectors is 7.5° wide and about 500 miles deep; together they cover a 240° annular barrier region that includes most of the United States and portions of the Pacific and the Atlantic Oceans and the Gulf of Mexico (see Figure 1-1). The inner edge of the barrier sector varies between 1,000 and 1,300 miles from the radar system. The operating frequency is independently selected for each 7.5-deg sector according to a number of criteria. Figure C-1 shows the major steps involved in selecting the frequency for one sector; the following paragraphs describe the process.

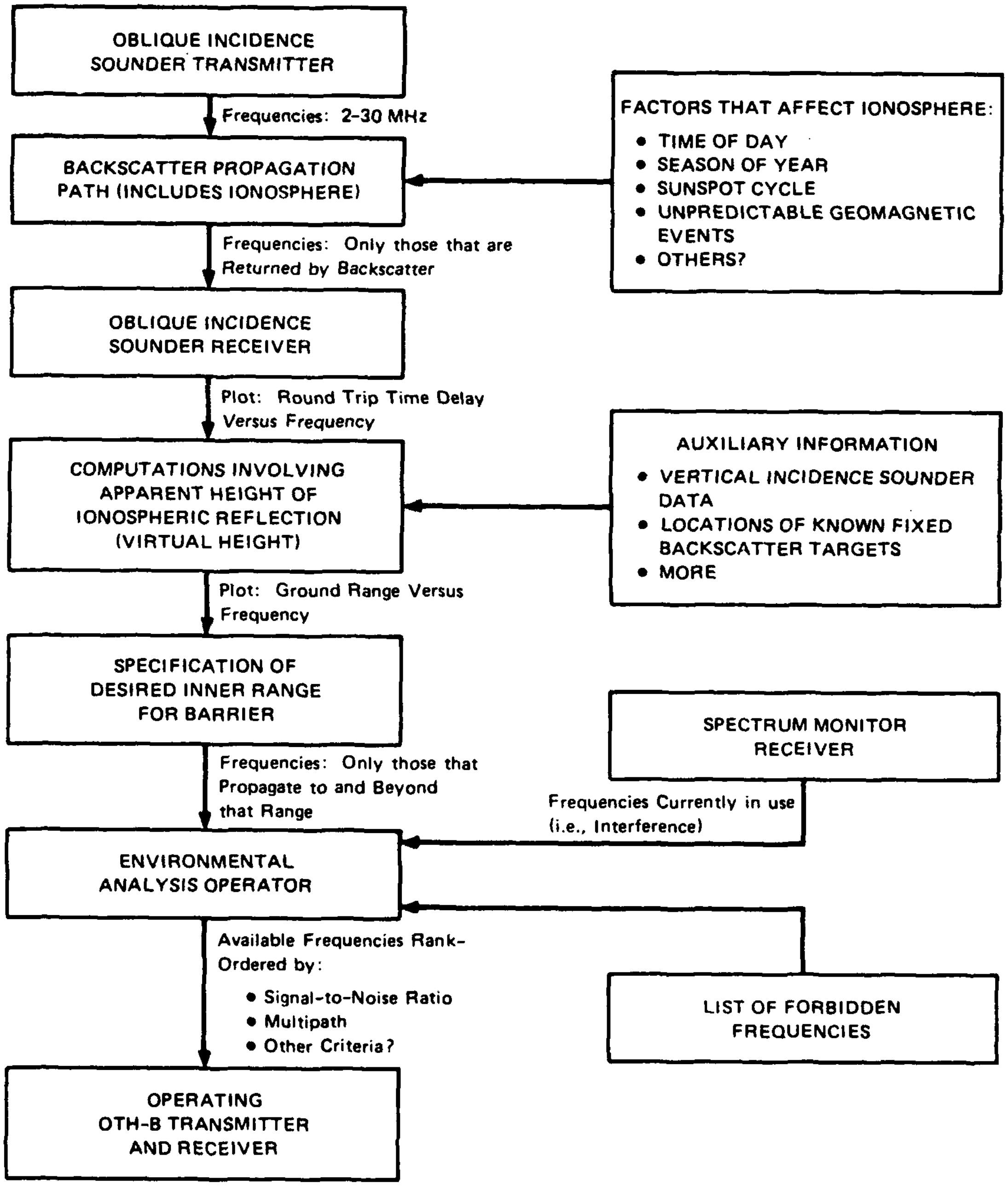


FIGURE C-1 CONCEPTS FOR SELECTION OF OTH-B OPERATING FREQUENCY FOR EACH 7.5-DEGREE SECTOR

A low-power oblique-incidence backscatter sounder transmitter at the OTH-B transmit site transmits signals over the 2- to 30-MHz frequency band toward the barrier sector. The ability of the ionosphere to reflect signals back to the earth at great distances is constantly changing. It depends on the electron density as a function of height, which is controlled by solar illumination and therefore has cyclical variations with time of day, season of the year, and the 11-year solar activity cycle. Noncyclical changes brought about by random solar activity such as solar storms also occur. Thus, only the signals in a fraction of this 28-MHz-wide band will be refracted by the ionosphere to illuminate the earth's surface and from there be reflected back along essentially the same ionospheric path to the backscatter sounder receiver at the OTH-B receive site. The lower end of this band of frequencies may be of little interest, as it may be determined essentially by overhead reflection. The upper end of the returned band of frequencies indicates the highest frequency that the local ionosphere will reflect at that time.

The raw data provided by the oblique sounder system could take the form of a plot showing the signal's round-trip time delay as a function of frequency (for those frequencies that are returned). The OTH-B system then uses auxiliary information, such as the locations of known, fixed backscatter targets, to convert the time delay to the equivalent ground range so that the data could be shown as a plot of ground range as a function of frequency (see Figure C-2).

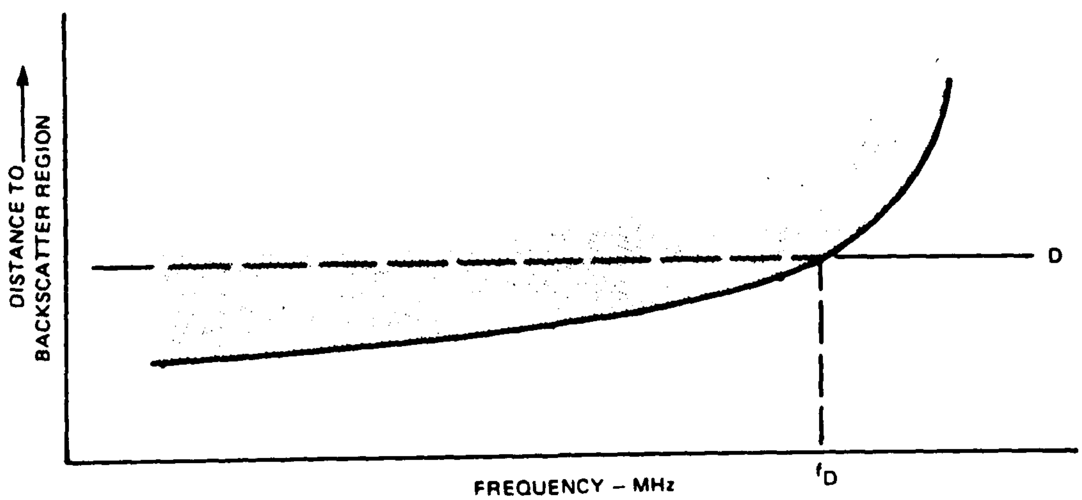


FIGURE C-2 CONCEPTUAL BACKSCATTER IONOGRAM SHOWING THAT FREQUENCIES ABOVE f_D CAN BE USED ONLY FOR DISTANCES BEYOND D

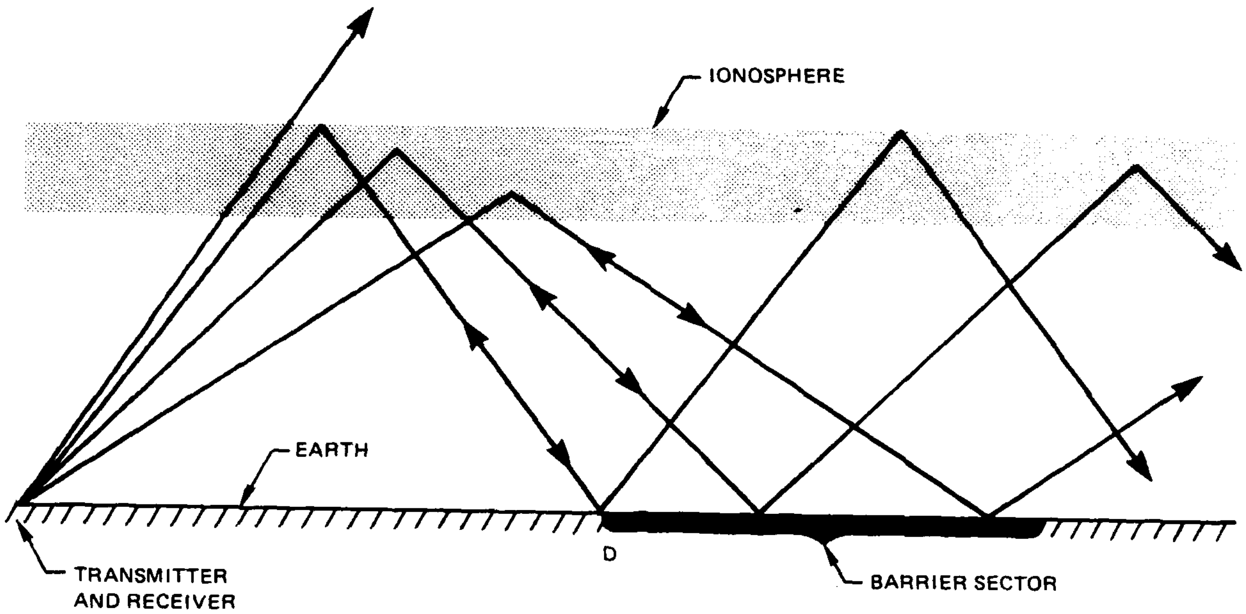
The radar-operator-specified-range to the inner edge of the barrier sector determines the band of frequencies that, strictly from the standpoint of propagation, could be used. Information such as that shown on Figure C-2 would indicate to the radar and its operators that the operator-specified minimum range D can be reached only by using frequencies below the frequency f_D.

Figure C-3 illustrates why this is so. The distance into the ionosphere that a signal at a given frequency will propagate before it is refracted back toward the earth depends on the angle at which it enters the ionosphere; the transmit antenna array, which has a broad pattern in the vertical plane, does not control this angle well. Propagation at the frequency f_D is illustrated in Figure C-3a. At low take-off angles, the signal propagates beyond the distance D into the desired barrier sector; as the take-off angle increases, the wave propagates further into the ionosphere before it is reflected, and the distance to the ground-reflection point eventually decreases to the specified minimum distance D. At take-off angles just steeper than that, the signal passes through the ionosphere and is not reflected back to the ground at all. Points closer than D receive no sky-wave signal at that frequency and are said to be in the "skip zone".

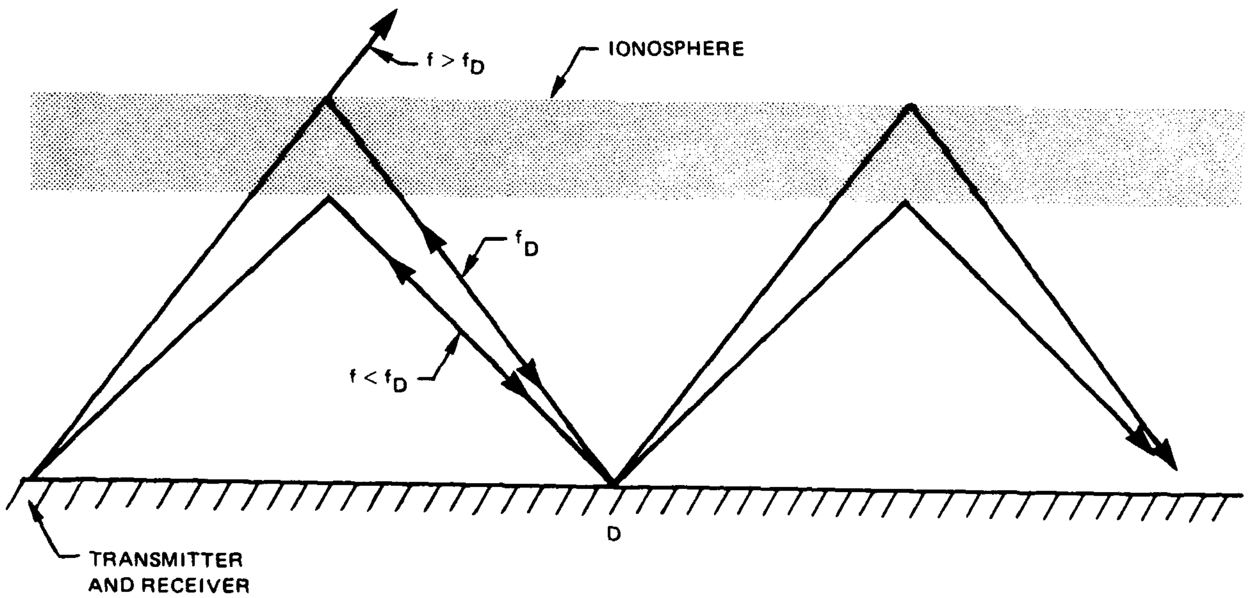
Figure C-3b demonstrates that frequencies less than and up to f_D propagate to the minimum distance D by means of increasingly greater take-off angles. At that maximum take-off angle, frequencies higher than f_D will penetrate the ionosphere; at lower take-off angles, however, these higher frequencies will propagate to minimum distances greater than the distance D.

The band of available frequencies extending up to f_D is then further constrained by the radar's Environmental Analysis Operator, who employs a spectrum monitor receiver to determine, in real time, on which frequencies signals are propagating to the receive site. The radar will generally not be operated on an occupied frequency because that would cause mutual interference. Other, apparently unoccupied, frequencies are used only for emergency traffic and are normally quiet, although they are guarded (i.e., monitored) by various agencies. Thus, the spectrum monitor receiver would generally not find signals on these frequencies. To avoid them, the OTH-B operators maintain a list of these forbidden frequencies; the radar transmitter cannot be operated on any of them. The remaining available frequencies are then ranked in terms of suitability, using criteria such as signal-to-noise ratio and multipath.

The ranked list of "most desirable allowable frequencies" applies only to the particular barrier sector from which the backscatter sounding and spectrum monitoring data were received, and the OTH-B transmitter will use only those frequencies in that sector. Other sectors will have identically derived lists, all of which will be constantly updated as ionospheric conditions change.



(a) PROPAGATION AT THE FREQUENCY F_D
FOR VARIOUS TAKE-OFF ANGLES



(b) PROPAGATION TO THE DISTANCE D BY
FREQUENCIES AT AND BELOW F_D

FIGURE C-3 SIMPLIFIED BACKSCATTER PROPAGATION PATHS

The radar does not generally scan an array's eight adjacent 7.5° sectors in any regular sequence. In fact, to counter any advantage an adversary might gain from a predictable scanning pattern, the radar may illuminate the sectors in an apparently random order. Each 7.5° sector will be revisited within 15 to 60 seconds, for an average dwell time of 2 to 8 seconds. If the radar does produce interference to any other users of the spectrum, these figures would indicate how often this would occur and how long it would last.

C.2.2 Power Transmitted at Various Frequencies

The power emitted by a radio transmitter is never confined completely to the intended bandwidth of operation. A transmitter typically emits some power within the spectrum adjacent to the operating band. It may also emit some power on frequencies that are integer multiples of the operating, or fundamental, frequency; these frequencies are called harmonics. Further, noise and spurious signals may be generated within portions of the transmitter system that are amplified and then radiated by the antenna system.

C.2.2.1 The Transmitted Spectrum in and near the Operating Band

The most common waveform of the OTH-B radar will be a linear frequency modulated/continuous wave (FM/CW) waveform such as is illustrated in Figure A-2, Appendix A. The three parameters--center frequency (f_0), period (T), and operating bandwidth (B)--are varied according to the needs of the radar system. The center frequency is selectable in 1-Hz increments within the 5- to 28-MHz band, and the signal sweeps within a selected operating bandwidth about that center frequency at some waveform repetition frequency (WRF), which is the inverse of T, shown in Figure A-1.

The modulation has been designed to minimize the transmitted power that falls outside the operating bandwidth so as to decrease the likelihood of interference to users of the adjacent radio spectrum. Figure C-4 shows the maximum allowable power spectral density (in a 1-Hz band) as a function of frequency offset (Δf) from the center frequency (Snyder, 1982). These simplified curves are upper bounds for the actual transmitted spectrum, which has a very complicated appearance. They show, for example, that for a radar operating bandwidth of 10 kHz and a WRF of 60 Hz, the power density at a frequency 20 kHz above or below the OTH-B center frequency will be at least 47 dB lower than the power density in the operating bandwidth. That is, if the radar is operating at its full 1.2-MW output power, the output power apparent to a receiver 20 kHz from the radar's center frequency is 47 dB lower (a factor of more than 50,000) than 1.2 MW, or only about 24 W. If the WRF is reduced to 20 Hz, the power density for the same Δf is about 6 dB (a factor of about 4) lower than at a WRF of 60 Hz.

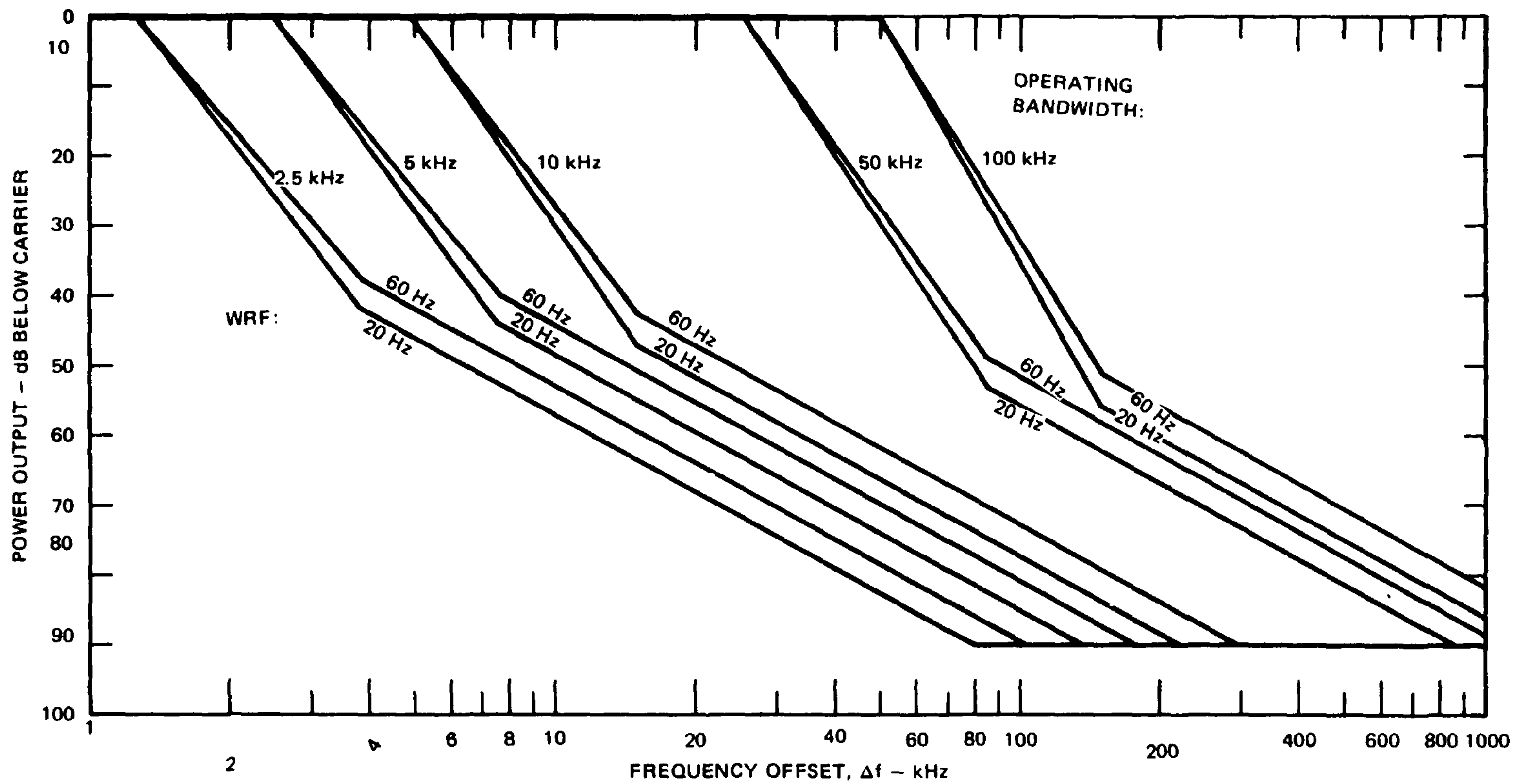


FIGURE C-4 THE ENVELOPE OF THE TRANSMITTED SPECTRUM—POWER DENSITY AS A FUNCTION OF OFFSET FROM THE CENTER FREQUENCY

C.2.2.2 Harmonics

The OTH-B system specification indicates that the harmonics from each transmit array shall be at least 70 dB weaker than the fundamental signal. This does not imply that radiated harmonics will be only 70 dB down from the radiated fundamental; they will be considerably weaker than that because the antenna system will not provide high gain at the harmonic frequencies. Recall that the transmit antenna system is a phased array. Each face has 12 transmitters, each supplying power to one dipole element of the band in use at the time. The system forms its high-gain, relatively narrow beam by carefully timing the transmitter output signals so that precise phase relationships exist between the signals emitted by each of the 12 dipole elements. This careful timing must account for the electrical length of the coaxial transmission line between the transmitter and the antenna, which is different for each of the 12 transmitter/antenna pairs. Further, the antenna elements are placed so that certain phase relationships exist between the signal directly radiated by each dipole element and those reflected from the groundscreen, the backscreen, and the adjacent dipoles. The appropriate phase relationships will not exist at harmonic frequencies, so that the harmonic signals radiated by the antenna system elements (and reflected from the groundscreen and backscreen) will be randomly phased. Therefore, the array will not form a high-gain beam at the harmonic frequencies as it does at the fundamental.

Table C-1 lists the frequency bands into which harmonics may fall, in order of decreasing amplitude at the output of the transmitter (Lyon, 1982); because of the phase scrambling described above, this particular order may not hold for the radiated harmonic signal. The gain of the antenna system is about 22 dBi at the fundamental frequency. Because the antenna system will not have a high gain at the harmonic frequencies, however, the radiated harmonic signals will be much more than 70 dB below the fundamental. Estimates of 80 to 90 dB are not unreasonable.

Table C-1

HARMONIC FREQUENCY BANDS OF THE OTH-B RADAR

Harmonic	Frequency Band (MHz)
Fundamental	5 to 28
2nd	10 to 56
4th	20 to 112
6th	30 to 168
3rd	15 to 84
8th	40 to 224
5th	25 to 140

Thus, because the effective isotropic radiated power (EIRP) of the radar at fundamental frequencies is about 82.8 dBW (the radar's output power of 1.2 MW, or 60.8 dBW, and its antenna gain of 160, or 22 dBi, yields an EIRP of 82.8), the EIRP at the harmonics will be on the order of 0 dBW (1 W) or much less.

C.2.2.3 Noise and Spurious Outputs

Transmitter noise and spurious output signals from the transmitters are to be at least 90 dB below the fundamental, when measured in a nominal 1-Hz bandwidth more than 2 Hz away from the fundamental. An exception is that harmonics of the 60-Hz power line frequency are required to be only at least 70 dB below the fundamental.

C.2.2.4 Power Reduction

The OTH-B radar will not need to be constantly operated at its full 1.2-MW power; when an adequate signal-to-noise ratio can be achieved with a lower output power, the radar's power level will be decreased independently for each 7.5° sector in steps of about 1 dB (Villard, 1980). The maximum available power reduction is about 15 dB, a factor of about 32; thus, the radar might sometimes operate using as little as 37 kW.

C.2.3 Signals Propagated by Sky Wave

Each of the 32 independent barrier sectors will be periodically illuminated by an ionospherically reflected sky-wave signal at a frequency selected as optimal for that sector at that time. The radar is highly adaptive. Because ionospheric propagation conditions are constantly changing and because the radar avoids frequencies that are obviously in use, predicting its detailed frequency use is impossible. The frequencies used will most likely be higher during the day than at night and in summer than in winter. Large frequency changes on any given sector will probably be required shortly after the sun strikes the ionosphere near the reflection region.

Regions other than the desired barrier sectors will also be illuminated by sky-wave signals. As Figure C-3 indicates, the signal may take another hop or more beyond the barrier sector, depending on the condition of the ionosphere at subsequent potential reflection regions. Further, the radar's backlobes, which are weaker than the main beam by at least 20 dB (a factor of 100), may propagate by sky wave to regions behind the radar that are approximately the same distance away as are the barrier sectors.

In addition to the fundamental and frequencies adjacent to the fundamental, some harmonics and spurious signals could propagate by sky wave. Only those below about 30 MHz could ever be expected to do so, and they would not necessarily propagate to the same regions as does the fundamental. Harmonics above about 30 MHz would not be reflected back to the earth by the ionosphere and so would not propagate to distant regions.

C.2.4 Signals Propagated by Ground Wave

Some of the energy radiated by the antenna system remains near the earth's surface, where it propagates by ground wave, becoming attenuated as a function of distance much more rapidly than does the sky wave. (Ground waves account for the daytime coverage of the AM broadcast stations.) Figures C-5 and C-6 show estimates of the field strength at 6 MHz and 25 MHz, respectively. These two frequencies are at the approximate centers of the lowest and the highest of the radar's six frequency bands. The field strengths were estimated using a computer formulation of the empirical propagation model of Norton (1941) for vertical polarization and low antenna heights, as discussed by Terman (1943) and by Duff and White (1972).

Two curves, labeled "in front of the radar" and "behind the radar," are shown for each frequency. In front of the radar applies roughly to the 240° azimuthal sector from about 56° to about 296°; that is, to the east, west, and south of the transmit site; similarly, behind the radar applies to regions in the 120-degree sector to the north. As in Appendix B, a 20-dB (i.e., 100-to-1) front-to-back ratio was used.

The ground constants used here are said to be typical of "marsh land," and are taken from a report by Sailors et al (1983). If actual measurements of the ground constants at the transmit study areas are made, calculations based on the measurements would provide improved estimates of ground-wave propagation.

At 25 MHz (band F), the antennas are vertically polarized and the curves are based on the full 82.8 dBW for the EIRP. At 6 MHz (band A), the antennas are rotated 45° so that one-half the power radiated is horizontally polarized; a horizontally polarized ground wave is attenuated so rapidly with distance that it can be ignored relative to the vertically polarized ground wave. Thus, we can consider the maximum available ground-wave EIRP for band A to be one-half the actual maximum, or 79.8 dBW.

For two reasons, these curves probably show field strengths considerably greater than would normally occur. First, the curves show field-strength estimates for the radar's maximum allowable EIRP, which would not be used at all times. The second reason that the curves are probably pessimistically high is that the model applies for a "smooth

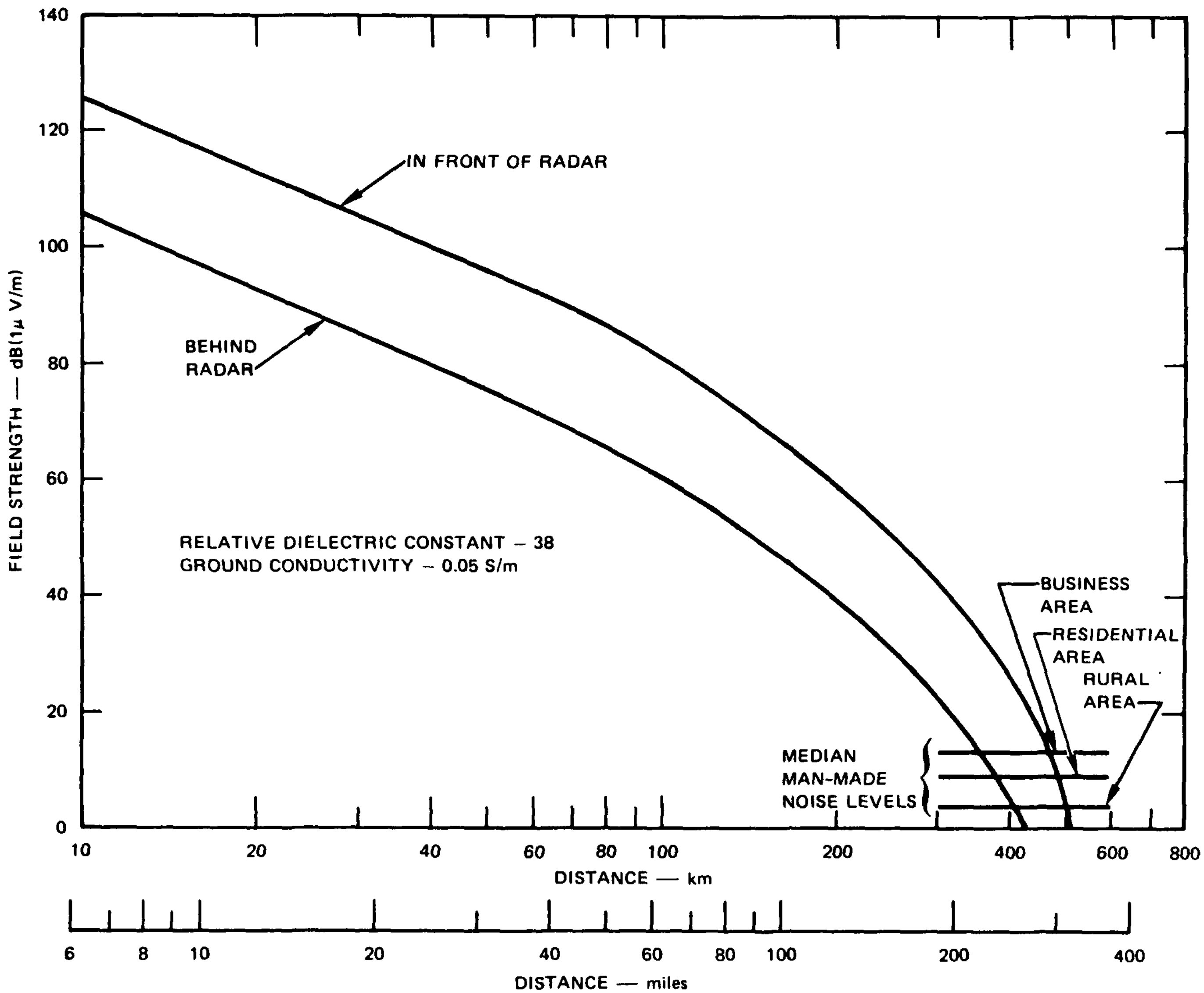


FIGURE C-5 VERTICALLY POLARIZED GROUND-WAVE FIELD STRENGTH — 6 MHz

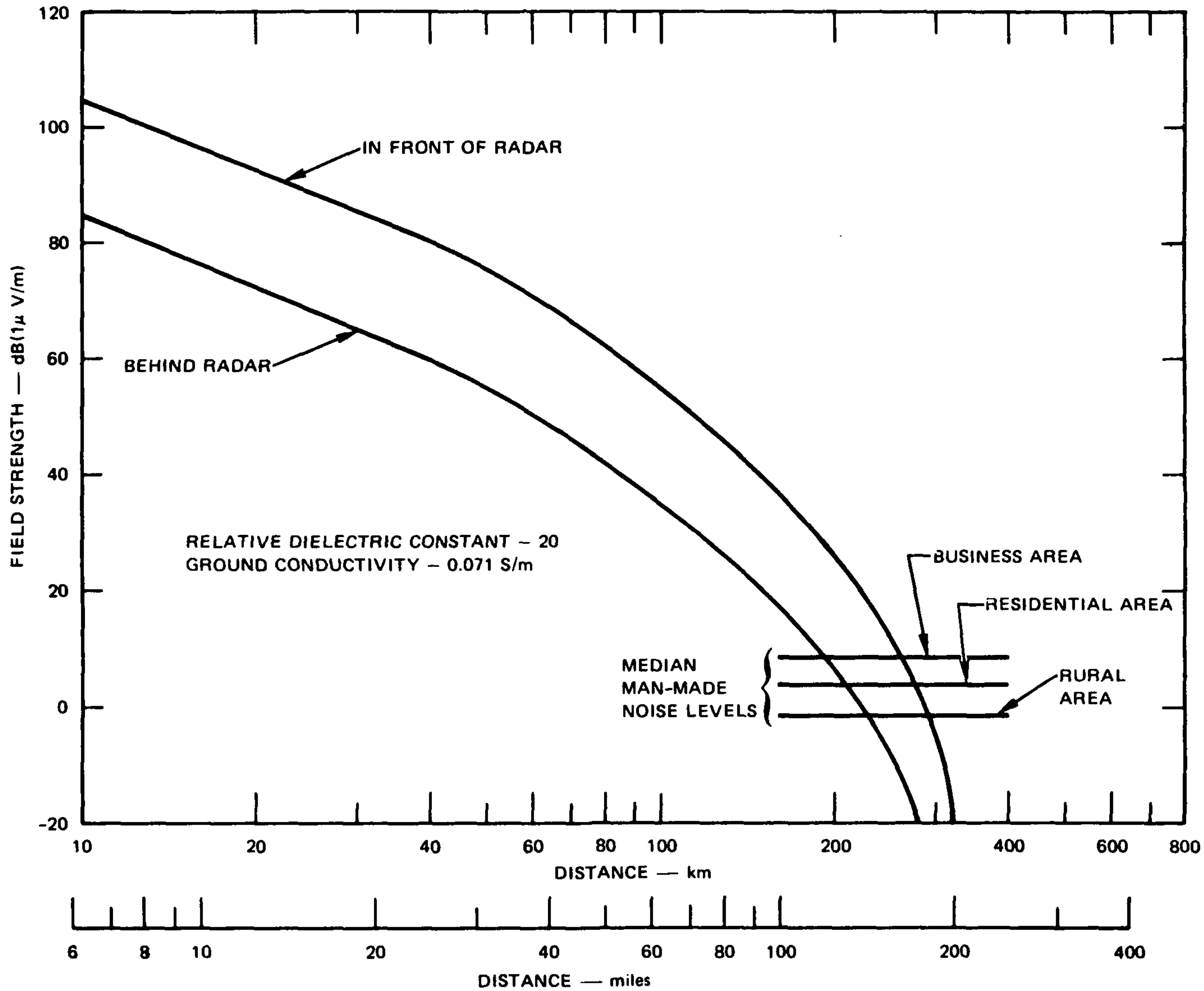


FIGURE C-6 VERTICALLY POLARIZED GROUND-WAVE FIELD STRENGTH — 25 MHz

spherical earth" with "uniform ground constants surrounded by an atmosphere in which the dielectric constant decreases uniformly with height," so that "the departures from these idealized conditions, such as hills, buildings, trees, etc., cause large variations from the calculated values" (Norton, 1941).

The limiting distance at which the OTH-B ground-wave signal could be received, provided that the receiver in question was tuned to a frequency in use or about to be used by OTH-B and that no other signals were in that frequency band, would be determined by the radio noise level in that same band at the receive site. If the power of the radio noise exceeds that of the OTH-B signal, the OTH-B signal will not be noticeable.

If the receiver were already tuned to some desired signal, the maximum distance at which the OTH-B ground wave could produce interference would be even less. To be noticeable, the OTH-B signal would have to exceed the combined power of the noise and the desired signal (which itself would have to exceed the noise to be useful).

The predominant noise in the HF band is seldom the internally generated noise of the receiver system. Instead, the predominant noise is usually that originating from natural or man-made sources and entering the receiving system through the antenna array. The most important source of naturally occurring noise at frequencies up to about 20 MHz is the thunderstorm; radio noise from lightning propagates by way of sky wave, so that major storm centers influence the noise on a global basis. Because the general times and locations of major thunderstorm activity and the nature of the seasonal and diurnal variations in sky-wave propagation are known, this atmospheric radio noise can be statistically predicted. Such predictions are available as a function of frequency, location, season, and time of day in a report most commonly referred to as CCIR 322 (C.C.I.R., 1964). Recently, the CCIR-322 atmospheric noise estimates have been improved (Spaulding and Washburn, 1985), and these improved estimates were used here. Above about 20 MHz, atmospheric noise, which decreases quite rapidly with increasing frequency, is likely to be exceeded by galactic radio noise, which originates from the stars and does not propagate from other areas of the earth by sky wave.

Man-made radio noise is the predominant noise at some frequencies in some areas--particularly in regions of high population density or heavy vehicle traffic. The major sources of man-made radio noise are high-voltage power transmission and distribution lines, automobile ignition systems, electrical motors, and fluorescent lights. Predictions of man-made noise are provided as a function of frequency for business areas, residential areas, and rural areas (C.C.I.R., 1976).

The noise predictions, which are expressed in terms of noise power available in a certain bandwidth at the terminals of an electrically short vertical antenna, can be converted to some other bandwidth and then to the equivalent field strength for comparison with the predictions of the ground-wave field strength produced by an OTH-B radar (Crippen, 1970). The median predicted noise field strength for the central United States, in a 6-kHz bandwidth at 6 MHz, is shown in Figure C-7, which clearly reveals the diurnal and seasonal variations in the atmospheric noise at that frequency. Although no such diurnal predictions are available for the man-made noise, it too can be expected to vary, being controlled by factors such as times of high traffic density, working times, and, for power line noise, local weather conditions. The figure shows that in a business area, the man-made noise at 6 MHz will predominate over the atmospheric noise except at night in the summer, and thus man-made noise usually constitutes the limiting factor in reception of signals. In a residential area, the man-made noise will predominate in the daytime, but at night the atmospheric noise will rise above the man-made noise, except during the winter. In a rural area, the atmospheric noise will exceed the man-made noise at night. Remote areas may exist where the man-made noise would be so low that the galactic noise would predominate during the daytime, although the galactic noise would be exceeded for the rest of the time by the atmospheric noise.

At 25 MHz, the atmospheric noise is so low that it is generally exceeded by the galactic noise. However, the man-made noise, even in rural areas, can be expected to be higher than the galactic noise, and so it would be the limiting factor in the reception of weak signals.

The noise information has been transferred to Figures C-5 and C-6 to indicate the distances at which the OTH-B ground-wave signal would be likely to drop below the prevailing daytime (man-made) radio noise. At night, the noise would be greater and the signal would drop below it at smaller distances. Note that a 6-MHz signal would propagate farther than a 25-MHz signal; frequencies between these two would propagate to intermediate distances. These pessimistic predictions show the ground wave as stronger than it would probably be; the figures show the OTH-B field strengths that would result from full authorized power and smooth-earth propagation. The radar, would not generally use its full power. Thus, we do not expect that the OTH-B ground wave will ever be detectable at distances as great as those suggested by these curves. Measured ground conductivity data will permit better predictions.

C.2.5 The Experimental Radar System

A version of the OTH-B system termed the Experimental Radar System (ERS) was built and operated in Maine to test and evaluate many of the radar's operational concepts and to determine the interference that might occur. The ERS had only one of the four independent arrays that the CRS would have. Antenna arrays were not constructed for bands A and F; only frequencies between 6.74 MHz and 22.25 MHz were available.

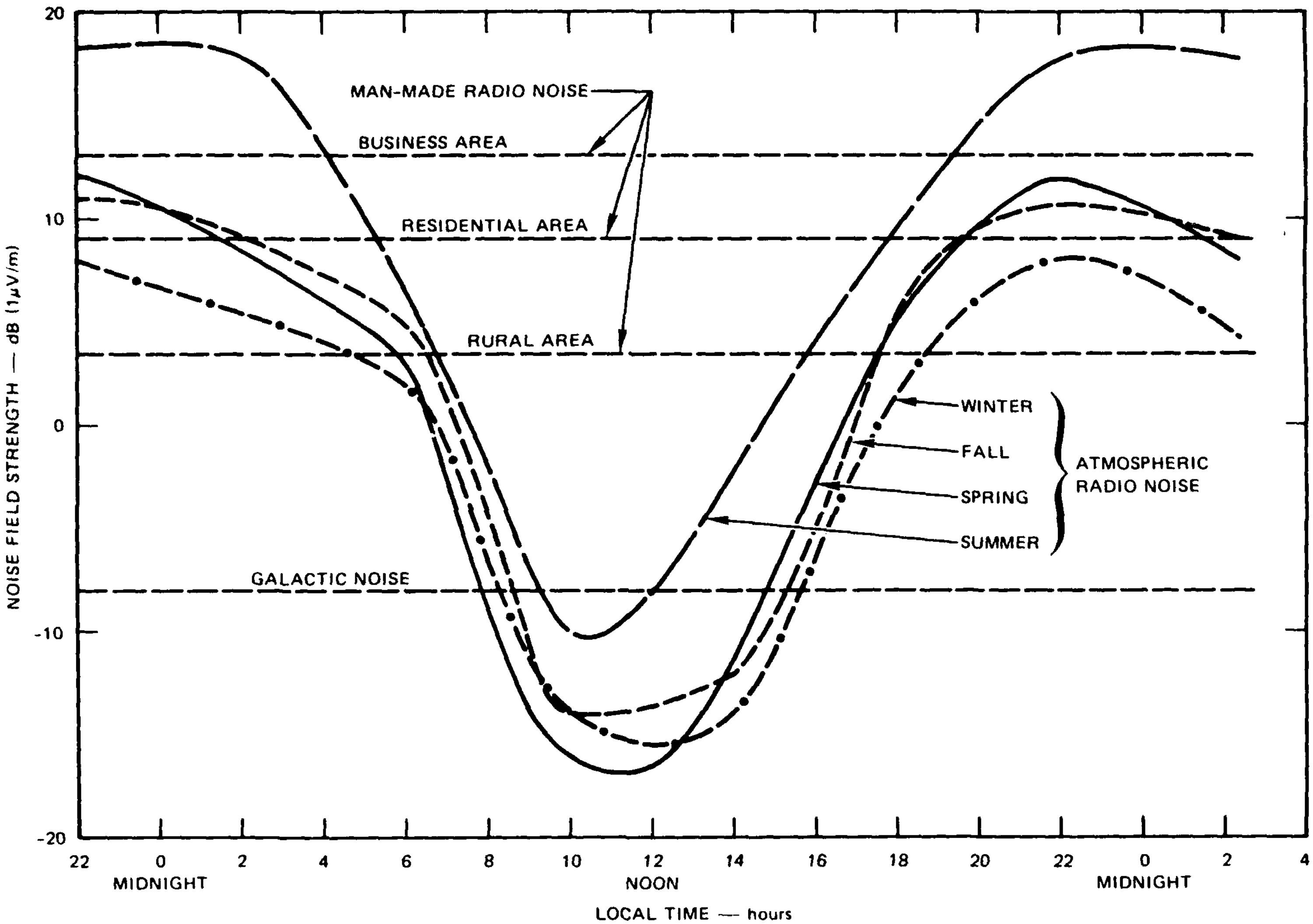


FIGURE C-7 RADIO NOISE ESTIMATES FOR CENTRAL U.S. AT 6 MHz (6 kHz Bandwidth)

The ERS was operated for about 1 year ending in January 1981. Although it did not generally operate 24-h/d, the radar was usually operated during the ionosphere's day-to-night and night-to-day transition periods, when frequency changes would most likely be needed. The ERS logged a total of about 900 hours of transmit time, with output power typically at about 720 kW. Some full-power tests were also run (Raffa, 1982).

C.3 OTH-B Effects on Systems

C.3.1 Telecommunication and Airnavigation Systems

C.3.1.1 Effects within the Radar's Authorized Operating Bands

The radar is authorized to operate within any of about 20 blocks of the radio spectrum between 5 MHz and 28 MHz that are also occupied by stations of the Fixed Service or the Broadcasting Service. Operation of the radar is intended to produce minimal interference with other users of these same portions of the spectrum, and operation of the ERS in Maine indicates that this can be achieved. Occupied channels are avoided both to prevent interference to others and to prevent others from interfering with the radar's operation. Over the more than 1 year that the ERS was operated, the Air Force determined that it generally had to change its operating frequency several times during an 8-hour shift to avoid interfering signals, but that clear 10-kHz channels for routine surveillance were always available, except for a brief time in the winter, when only 5-kHz channels could be found.

Of the two services, the Broadcasting Service is less likely to share the bands with the radar. Air Force operating procedure will be to attempt to "find an unused frequency in the fixed (point-to-point) section of the HF spectrum" (Thomas, 1980), and the "policy is to conscientiously avoid the use of the SWBC (short wave broadcast bands) wherever possible" (Bayer, 1981). Both Fixed and Broadcast Services generally can change their frequency, either to respond to changing ionospheric conditions or to serve different parts of the world. Broadcast stations often use several transmitters to transmit simultaneously on more than one frequency.

To avoid producing interference to the greatest number of other receivers, use of the Fixed bands is a reasonable policy and will be adhered to whenever possible. In the Fixed Service, transmissions are intended to be point-to-point; only two stations are involved, and only the receiver is potentially susceptible to interference from the radar. No others are authorized to receive these transmissions. On the other hand, "broadcast" implies the existence of numerous intended receivers, any of which might be susceptible. When operating in the Fixed band, the radar will stay far enough away from the band edges to minimize the possibility of interference to other users, such as broadcast receivers.

Although intermittent operation of the ERS for more than a year produced several complaints of interference, only one actually corresponded in time and frequency with an ERS transmission. All reported complaints are listed in Table C-2, which shows that the ERS was generally not operating when the interference was claimed. The single possibly valid complaint was logged by a Military Affiliate Radio System (MARS) station in Florida, which is a Fixed station that uses 20.9375 MHz on a "limited schedule basis" (Abel, 1981) to pass message traffic to military families stationed in Germany. The radar was already operating on the frequency at the time the MARS station was expecting to use it, making it impossible for the MARS station to do so. This one-time problem was resolved within the military.

The CRS will differ from the ERS in that it will have four independently operating transmit arrays instead of one; it will be able to transmit on band A (5.0-6.74 MHz) and band F (22.25-28.00 MHz), which were not available to the ERS; its maximum available transmitter power will be slightly greater; and, it will operate continuously. Like the ERS, the CRS will have the clean spectrum illustrated in Figure C-4, which limits the likelihood of adjacent-channel interference.

The probability of interference to HF reception by the radar's ground-wave signal is slight. As has been pointed out, the ground wave will quickly be attenuated by distance to levels below the ambient noise. It will be undetectable at distances beyond about a very few hundred miles--or possibly much less; thus, only HF listeners within a limited range could possibly detect the ground-wave signal. Because the radar study areas are far removed from any major population center, the number of such listeners is small. If an HF listener were within the range of the ground-wave signal and receiving a sky-wave signal from some distant transmitting station, however, that signal would also most likely be received by the radar, and the frequency would therefore be rejected as an operating frequency.

The probability of interference by the radar's sky-wave signal is higher, and such interference could occur virtually any place at locations one or more ionospheric hops distant from the transmitter. Interference could occur if a distant transmitter were propagating a signal to various parts of the world that, because of ionospheric propagation conditions, did not include the radar site. (As one simple example, if an HF transmitter were about 100 miles away, neither its ground wave nor its sky wave would reach the radar.) In that situation, although the radar system monitors the spectrum before transmitting, the radar operators would believe that the in-use channel was clear and would feel free to use it. They could not realize that the radar signal could be producing interference at some far distant location, depending on the relative levels there of the radar signal and the desired signal. Because the radar signal involved could be emitted by the main lobe, backlobes, or sidelobes, and because the signal could propagate by more than one hop, predicting when or where this may occur is impossible.

Table C-2

REPORTS OF ERS INTERFERENCE

Date and Time (1980)	Location	Frequency (MHz)	Service	Source of Information[a]	Assessment
15 Feb through 4 March (8 hours)	Jonesport, ME	54-60 76-82	TV channels 2 and 5	A	ERS transmitted for only 4 min during reported interference periods.
22 April	Canal Zone	18.019	Aeronautical Mobile	A	ERS transmitting on 10.540 MHz.
23 April	Canal Zone	18.019	Aeronautical Mobile	A	ERS not transmitting during reported interference period.
29 April, 2019Z	Not stated	10.54	Fixed	R	ERS not operating at the time.
8 July	Sweden	15.255	Broadcast	A	ERS transmitting on 11.605 MHz
8 July, 1923Z	Not stated	15.245	Broadcast	R	ERS not operating at the time.
Not stated	Not stated	3.975	Amateur, Fixed, & Broadcasting[b]	R	Not within the ERS frequency range.
16 Sept.	Philadelphia, PA	21.780-21.795	Fixed	A	ERS transmitted successively on 20.944, 20,815, and 20.096 MHz during the reported interference period.
16 Sept., 1430Z	Not stated	20.944	Fixed	R	ERS not operating at the time.
16 Sept., 1446Z	Not stated	20.815	Fixed	R	ERS not operating at the time.
16 Sept., 1557Z	Not stated	17.775	Broadcast	R	ERS not operating at the time.
16 Sept., 1846Z	Not stated	20.096	Fixed	R	ERS not operating at the time.
16 Sept., 20??Z	Not stated	21.780	Fixed	R	ERS not operating at the time.
17 Sept., 2036Z	Not stated	21.770	Fixed	R	ERS not on this frequency.
30 Jan. 1981	Florida	20.9375	Fixed (MARS)	A	ERS was transmitting on this frequency, which the MARS station uses on a limited schedule basis.

[a]Sources: "A" refers to Abel (1981); "R" refers to private communication from Raffa (1982).

[b]Services that might be on 3.975 MHz vary from one part of the world to another.

This interference would not necessarily be constant. Each of the radar's four arrays switches its beam to sequentially illuminate its eight 7.5° barrier sectors, and it would use the same or different frequencies for each. If the same frequency were in use, the interference might occur only for the roughly one-eighth of the time the radar's beam is directed appropriately. If different frequencies were used for each barrier sector, the interference would occur only for the approximately one-eighth of the time the radar was using the one particular interfering frequency. The Air Force does not wish to release precise information on how long the radar would typically keep its beam on a given barrier sector or how often it would probably revisit it, and so we can make no definitive statements regarding the duration of such an interference episode or the interval between them. Some evidence shows that the duration might be as short as 10 seconds, however, which would imply that the interference would occur in 10-second episodes every 80 seconds.

The Air Force wishes to operate the radar without interference to others. Those who believe that they are experiencing interference from it are urged to keep an accurate log of the times and the frequencies and to provide that information to the Air Force. The address is: HQ ESD/SCO, Hanscom Air Force Base, MA 01731-5000.

C.3.1.2 Effects Outside the Radar's Authorized Operating Bands

C.3.1.2.1 Effects on Amateur Radio

The Amateur Radio Service occupies several bands within or adjacent to the range of frequencies used by the radar (see Table C-3). Except for the 40-m band, all are set aside worldwide for the exclusive use of the amateurs. (The 40-m band is used by amateurs only in North and South America; in the rest of the world, it is allocated to broadcasting.) Because these bands are among those that can be supported by ionospheric propagation, the amateurs use them for contact with other amateurs throughout the world. Although contact is casual, the amateurs have often provided urgently needed emergency communication services following disasters such as tropical storms, tornados, or earthquakes.

Table C-3

AMATEUR RADIO BANDS NEAR THE RADAR'S FREQUENCIES

Common Terminology	Frequency Band (MHz)
40-m band	7.0 - 7.3
20-m band	14.0 - 14.35
15-m band	21.0 - 21.45
10-m band	28.0 - 29.7

Although the Air Force does not intend to operate the OTH-B radar in the amateur bands, all bands listed in Table C-3 are adjacent to bands in which the radar can be expected to operate. Thus, enough of the radar's energy could possibly fall into an amateur band to produce interference to the users there (see Section C.2.2.1). Because the energy could be emitted by the radar's sidelobes or backlobes, as well as the main beam, and because it could propagate by sky wave, specifically predicting when or where any interference would occur is impossible.

A 5-page article describing the ERS and the interference effects that might occur was published in a leading amateur radio magazine in 1980, about the time the Air Force began testing the ERS (Villard, 1980). The amateurs were informed that the radar, if heard on an AM receiver, would sound like a hum "at any one of several modulation frequencies from 20 Hz to 60 Hz," which are, of course, the WRFs. The article not only urged the amateurs to submit reports of any interference to the OTH Radar Office at Hanscom AFB, but it also stated that the "Air Force will welcome amateur reports of its signals and their apparent level, whether there is interference or not" (Villard, 1980).

No reports of ERS-produced interference in the amateur bands were ever received at the OTH-B Program Office (Raffa, 1982; Abel, 1981), indicating that this type of radar can operate without unduly affecting users of the adjacent channels.

C.3.1.2.2 <u>Interference to Television</u>

C.3.1.2.2.1 <u>The Television Environment in General</u>

In the United States, television is broadcast in two frequency bands: The VHF TV channels (those from channel 2 through 13) occupy portions of the spectrum between 54 MHz and 216 MHz; the UHF channels (those from channel 14 through 69) occupy the continuous spectrum between 470 MHz and 806 MHz. The OTH-B radar will occupy portions of the spectrum between 5 MHz and 28 MHz, well below the frequencies used for TV broadcast.

When applying for a license to operate, a TV station's engineers calculate and provide contours of predicted TV signal strength that define the station's intended coverage area. These are statistical predictions because they cannot take into account all the many variables of terrain, location, and equipment that affect the reception. At the Grade A contour, by definition, the median field strength at a standard 30-ft antenna height must be sufficient to provide service (at the best 70% of the receiving locations) that the median observer would consider "acceptable" at least 90% of the time, using an antenna equivalent to a half-wave dipole (i.e., a rabbit-ear antenna). At the more distant Grade B contour, the median field strength at the standard antenna

height must be that which provides the observer with "acceptable" TV reception at only the best 50% of the receiving locations and only if an antenna with a gain 6 dB higher than that of a dipole is used. (Such an antenna would probably be a multielement Yagi.) The locations of the Grade A and Grade B contours are determined using FCC-approved methods to predict the signal strengths.

Increasingly, cable TV systems are being used to provide TV service to subscribers for a monthly subscription cost. Although each cable system is likely to be unique, the three major sources for their programming are:

(1) Reception of TV broadcasts directly off the air, but typically using a higher tower and better antennas than the home viewer has available.

(2) Terrestrial microwave links from distant cities.

(3) Geostationary satellites.

In some (generally mountainous) areas, TV coverage is available only from low-power translators, generally installed on a high hill or mountain peak, where direct reception from a distant TV transmitter is possible. After the translator receives the direct broadcast TV signal (usually using a high-gain directional antenna), it amplifies and rebroadcasts the signal on another channel at relatively low power to provide service within a small area.

Increasingly, those living in remote areas served poorly, or not served at all, by TV broadcast stations receive television directly from geostationary satellite transmission in the 3.7- to 4.2-GHz band using privately owned earth stations. Such systems are becoming more popular because they can provide high-quality television reception of many channels and their price has dropped in the last few years to the $2,000 to $5,000 range.

C.3.1.2.2.2 The TV Environment near the Candidate Transmitter Sites

Although no detailed study has yet been conducted to determine specific of the TV environment in the vicinities of the CRS transmit study areas, it is apparent that the regions are not blanketed by numerous TV signals, as are the larger metropolitan areas. Because of the lack of mountain tops or exceedingly tall buildings for placing TV transmitting antennas, the central states use some of the nation's highest towers--some over 2,000 ft tall. It is doubtful that TV repeaters are widely used in the area; they are typically needed in mountainous regions, rather than on the plains. The extent to which subscription cable-TV sytems are in use in the vicinities of the study areas has not yet been determined.

The Television and Cable Factbook (1983) suggests that TV viewers in the vicinities of the Amherst study area probably obtain their strongest signals from KDLO (Channel 3) and from KABY (Channel 9); KDLO transmits from a 1,705-ft tower near Garden City, and KABY from a 1,288-ft tower near Crandall. The Amherst study area is approximately at the Grade A contours of both of these stations. Although no other stations include the Amherst study area even within their Grade B contours, or are closer than about 110 miles, it is entirely possible that some viewers having particularly good, or highly placed, antennas would receive adequate signals from the more distant stations. It is, of course, these lower level TV signals that would be most likely to experience interference.

The strongest TV signal in the Wheaton study areas is probably that of KCMT (Channel 7), which transmits from a 1,130-ft tower near Alexandria, Minnesota, but residents of that area probably also receive KDLO (Channel 3) and KABY (Channel 9) well; KDLO has the facilities mentioned above, and KABY's antenna is located 1,288 ft above the ground near Crandall, South Dakota. Very likely, some TV reception is possible from other stations, such as those near Fargo, North Dakota, even though the Wheaton study areas are beyond the Grade B coverage contours of any other TV stations.

C.3.1.2.2.3 Common Interference Mechanisms

Interference from the radar's harmonic or spurious emissions could occur if the emission falls in a TV channel being viewed, and if it is of sufficient strength relative to the TV signal to noticeably degrade video or audio quality. The TV picture is normally much more susceptible to interference than the audio portion. According to information provided to Abel (1980a), the lowest ratio of picture-carrier power to interference power at which a trained observer can notice interference is 46 dB. This signal-to-interference ratio would be the threshold to use in attempting to determine areas where interference to TV might take place. To do that, however, would require information regarding the exact locations of the radar and of the TV receivers in question. Such calculations cannot yet be done.

Fundamental overload and high-power interference effects could occur to a TV receiver only within a very few miles of the transmitter site. Fundamental overload could occur (usually only at VHF TV channels) if the fundamental signal from the OTH-B transmit site were strong enough at the TV set's antenna terminals to overload the TV tuner's input circuitry. Modern TV receivers, however, are typically equipped with a simple high-pass filter in the tuner's antenna input to provide a moderate degree of overload protection from signals at frequencies below the TV broadcast band. For extreme cases, for which the internal filter is inadequate, an external filter could be installed in the antenna lead to provide additional protection.

Antenna-mounted preamplifiers, sometimes used for improved reception in low-signal-level areas, are often quite susceptible to fundamental overload. When this type of interference occurs, the remedy is to install a high-pass filter between the antenna and the preamplifier. Several manufacturers make such high-pass filters for installation inside the preamplifier case.

High-power interference effects occur when a receiver is so close to the transmitter that the RF energy coupled either directly into the receiver circuits, or through the power line is sufficient to produce inter- ference.

No interference to direct satellite TV receiving systems should occur, because of the great separation between the satellite frequencies and those of the OTH-B radar.

C.3.1.2.2.4 TV Interference Experience at the ERS

Measurements in Maine in the vicinity of the ERS indicated that at distances of 6 miles or more from the radar, the radar's harmonics that could potentially interfere with television were much weaker than predicted and were generally so weak that they were not detectable above the background radio noise (Abel, 1980a). This indicates that they could not produce interference at such distances; no complaints of TV interference were ever logged.

Similar results could be expected in the vicinity of the CRS.

C.3.1.2.2.5 Assessment of the Likelihood of Interference to Television

C.3.1.2.2.5.1 General

High-power effects could be considered likely only at TV viewing households within a very few miles of the radar.

Fundamental overload interference would also be likely only for TV receivers within a very few miles. Any such cases could be inexpensively remedied by installing high-pass filters in the TV receiving system.

The interference resulting from the radar's harmonic or spurious emissions, however, could interfere either with direct-broadcast TV reception in the area or with the reception of any translators' signals. Because harmonic interference depends on the appropriate frequency relationships between the TV frequency and the frequency in use by the radar, the interference would be intermittent if it ever were to occur. The radar would have to be transmitting on the appropriate subharmonic of the TV signal. As an example, the picture carrier of a Channel-3 signal, such as that from KDLO, is at about 61.25 MHz. For third-harmonic interference, the radar would have to be using a frequency very close to 20.42 MHz.

Even given that the frequency relationships might sometimes be appropriate to produce interference, the actual occurrence of interference from the harmonics or spurious signals depends on a number of imperfectly predictable factors. Among them are: (1) the level of the radar's emissions in the TV channel; (2) the field strength of the TV signal at the receiver location; (3) the directional characteristics and the orientation of the TV receiving antenna relative to the OTH-B radar site; and (4) the distance and terrain characteristics between the OTH-B radar transmitter site and the TV receiving location.

Predicting interference for each TV receiver in any general area is not feasible, and so "typical" cases are often considered. Because of the great uncertainties and range of variability of the factors listed above, however, when the results of interference prediction calculations for so-called typical cases are eventually compared with actual experience, the actual results can be significantly different.

C.3.1.2.2.5.2 Specific Likelihood of TV Interference

Although methods exist for estimating the likelihood that the CRS transmitters will interfere with the reception of broadcast TV, insufficient information is available to make use of the methods. In general, interference predictions are based on determining and comparing the levels, at the victim receiver, of both the desired TV signal and the undesired radar signal. Those levels must be either measured or calculated on the basis of the location of the victim receiver relative to the TV station and to the radar transmitter. Information on the characteristics and pointing direction of the TV viewer's antenna is also necessary.

It is probable that TV interference will not be experienced more than 5 miles or so from the CRS transmitters, but the study areas are so large that the eventual location of the transmit antennas relative to any potentially victims of TV interference cannot yet be specified, and this is a key factor, as described above.

Also, mitigating measures are available for most forms of TV interference. If it is determined that certain harmonics of the OTH-B signal produce interference with reception, then it will be possible to restrict the radar from using the particular frequency that interferes. Other forms of interference can be corrected using appropriate filters. the Air Force will be extremely cooperative in correcting any interference problems that might occur.

C.3.1.2.3 Effects on Land Mobile Radio

The MITRE Corporation made measurements to indicate whether ERS harmonics would be likely to produce an interference threat to low-band VHF (roughly 30 to 50 MHz) mobile radio (Abel, 1981). As the ERS was operating, measurements were made on 10 frequencies between about 32 MHz

and 57 MHz that were second, third, fourth, or fifth harmonics of the ERS transmitted frequencies. MITRE performed the measurements at distances of 1, 2, and 3 miles from the ERS. At 1 mile, measurable ERS harmonic signals could be found on 5 of the 10 frequencies; on the other 5 frequencies, the ERS harmonics were so low that they were undetectable below the ambient noise level. At the 2-mile distance, only three of the ERS harmonics were above the noise; none of these was measurable at 1 mile, which suggests the expected randomness in the antenna pattern at the harmonic frequencies. At 3 miles, none of the harmonics was evident above the ambient noise.

The measurements suggest that there is about a 50% chance of harmonic interference in the low VHF land mobile band if the receiver is receiving a very weak signal and is only 1 mile from the transmitter. At a 2-mile distance, the chances have decreased to about 30%, and at 3 miles the chances are so very slight that the potentially interfering harmonics could not be measured. So far as is known, no actual interference with low-band VHF land mobile radio occurred, even though the Scott Paper company operated such communications equipment on a frequency near 50 MHz in the area within several miles of the ERS transmit site.

These results indicate that the CRS is also unlikely to produce interference to similar land mobile radio systems at distances greater than 3 or 4 miles.

During some ground-level power density measurements in June 1981, the measurement team coordinated frequency changes and beam steering using small, hand-held, portable VHF handy-talkies operating at 154.6 MHz (see Section B.8). No interference was ever noted. One portable unit was inside the transmitter building, using an external antenna. It communicated with the other, which was used directly behind the backscreen, at the end of the antenna array, and at a number of points along the exclusion fence, including points about 2,000 ft directly in front of the antenna array.

This test simply demonstrates that the radar does not necessarily interfere with radio communication in its immediate vicinity. The ERS frequencies used during this test included one near the midpoint of each of that radar's four bands; none of these, however, were subharmonics of the VHF handy-talky frequencies.

C.3.1.2.4 Effects on AM and FM Radio Reception

Operation of the CRS is not expected to interfere with reception of broadcast radio beyond about 2 miles from the radar site. According to Abel (1981), MITRE monitored AM and FM radio broadcasts on an automobile radio at a number of locations along the ERS transmitter access road and along other roads near the transmitting site while the ERS was operating. They determined that the ERS produced no interference in either the AM or FM broadcast bands at distances greater than about 1 mile from the ERS transmit antenna.

The maximum output power of the CRS is to be slightly greater than that used during testing of the ERS. Furthermore, because the conductivity of the ground surrounding it is higher than that of the ground in Maine, ground-wave propagation will be somewhat better. In view of these facts, the observations described by Abel can be extrapolated to suggest that interference could be expected in front of the CRS at distances slightly greater than 1 mile, and perhaps as far away as 2 miles or more.

C.3.1.2.5 Airborne Communication and Airnavigation Systems

C.3.1.2.5.1 Air-to-Ground Communications

When within radio line of sight of ground stations, aircraft use VHF frequencies, some of which are in the 118- to 132-MHz band. When at sea, beyond radio line of sight of ground stations, they are forced to use HF radio communications.

C.3.1.2.5.1.1 HF Air-to-Ground Communications

Because some aeronautical mobile bands are adjacent to the bands to be used by the OTH-B radar, aircraft flying at sea could be illuminated from above by the radar using a signal close to the aircraft's communication frequency. Abel (1980b) studied the matter to determine the guardbands necessary to prevent the ERS from producing adjacent-channel interference. He found that 16-kHz guardbands would sometimes be needed, although sometimes narrower guardbands would be adequate. These results depend on the radar's power level and on ionospheric propagation conditions and may be slightly different for the CRS.

C.3.1.2.5.1.2 VHF Air-to-Ground Communications

The VHF air-mobile communication frequencies in the 118- to 132-MHz band may be susceptible to fifth harmonics of the radar when it transmits on frequencies in the 23.6- to 26.4-MHz range and to sixth harmonics when it transmits between 19.67 MHz and 22.0 MHz. Abel (1980b) calculated that the ERS would not produce interference to airborne VHF receivers at distances beyond about 16 miles. Since the calculation had to be based on assumptions (regarding the harmonic suppression of the radar and the gain of the antenna at the harmonic frequencies) that could easily be in error by several decibels, the calculated distance could also differ considerably from what would actually be found. Although there is no indication that this 16-mile prediction was ever checked during the VOR tests described in the following subsection, no one complained of interference to airborne communications during the period of more than a year that the ERS was operated.

The CRS will have only slightly more available power than the ERS had during testing. If both radars were using their maximum available power, a given power density in the sky would be found at a distance from this radar about 1.15 times as great as from the ERS. Thus, although the CRS's potential for causing interference to airborne VHF communications is slightly greater, experience at the ERS suggests that such interference will not become a problem.

C.3.1.2.5.2 Air Navigation

Radio-operated aids to air navigation consist of equipment in the aircraft and ground stations maintained throughout the United States by the FAA. There are numerous ground stations in the vicinities of the CRS transmit study areas. Aircraft using these systems will be illuminated by CRS, and experience at the ERS suggests that interference to some aircraft receivers would probably occur if the radar were to transmit on certain frequencies. These frequencies could be determined and the radar could be forbidden to use them.

C.3.1.2.5.2.1 VOR, VORTAC, and VOR/DME

Aircraft can obtain bearing information from a VHF Omnirange (VOR) transmitting station. Each VOR ground station operates in one of about 100 channels in the 108- to 118-MHz band (just above the FM broadcast band). The transmitter radiates signals that the receiver system in the aircraft can use to determine the bearing from the aircraft to the ground station. Distance-measuring equipment (DME) enables an aircraft to determine its distance from the ground-based DME station, using channels in the 960-1,215 MHz band. It is very common to co-locate a VOR station and a DME station so that an aircraft can determine both its distance and its direction from the station, which is then referred to as a VOR/DME. When a VOR is co-located with a military distance-measuring system called TACAN (for Tactical Air Navigation system), the combined facility, from which either a civil or a military aircraft can determine both its distance and its direction, is called a VORTAC. Like DME, the TACAN portion of the VORTAC operates in the 960- to 1215-MHz band. There are both VOR/DME and TACAN stations in the vicinities of the CRS transmit study areas, and those within roughly 75 miles are listed in Table C-4 and are indicated on the map in Figure C-8. Under ideal conditions, a VOR can be used at distances to about 130 nautical miles (150 miles) by an aircraft at 18,000 ft, and at greater distances if the aircraft is at higher altitudes (FAA 1968). Similar distances almost certainly apply to the bearing-measuring part of the VORTAC and VOR/DME.

The map in Figure C-8 indicates the official air routes near the transmit study areas. The routes (designated "V") shown interconnecting the four VORTACs are the Low Altitude Federal Airways that may be used at altitudes up to 18,000 ft above mean sea level (MSL). They continue

Table C-4

VOR STATIONS AND NON-DIRECTIONAL BEACONS WITHIN ABOUT 75 MILES OF THE OTH-B TRANSMIT STUDY AREAS

Call Letters	Location	Channel (miles)	Operating Frequency (MHz)	Subharmonics (MHz) Fifth	Sixth
VORTACs					
ABR	Aberdeen	Ch 77	113.0	22.60	18.83
ATY	Watertown	Ch 113	116.6	23.32	19.43
FAR	Fargo	Ch 109	116.2	23.24	19.37
HON	Huron	Ch 123	117.6	23.52	19.60
VOR/DMEs					
MVE	Montevideo	Ch 53	111.6	22.32	18.60
MOX	Morris	Ch 33	109.6	21.92	18.27
FFM	Fergus Falls	Ch 41	110.4	22.08	18.40

Non-Directional Beacons (NDBs) and their frequencies

BTN	Britton	386 kHz
GWR	Gwinner	278 kHz
ETH	Wheaton	326 kHz
BWP	Wahpeton	233 kHz
VVV	Ortonville	332 kHz
BBB	Benson	239 kHz
DXX	Dawson-Madison	227 kHz

Source: U.S. Department of Commerce, 1986.

beyond the segments shown in the figure). These are only the major routes in the area. Aircraft flights are not limited to such routes, and aircraft will certainly be traversing this region on other routes. They will be coming from and going to the airports equipped with the VOR/DMEs, as well as those with the NDBs. Furthermore, some aircraft are equipped with inertial navigation systems so that they are not reliant on the VOR or beacon system. In short, aircraft may be flying courses over any portion of the land near the transmit study areas.

C.3.1.2.5.2.2 Experience with the ERS

Under some circumstances, an OTH-B radar can produce interference with an aircraft's VOR receiver if the radar is transmitting on or near frequencies that are subharmonics of the VOR's frequency (Abel, 1981)--

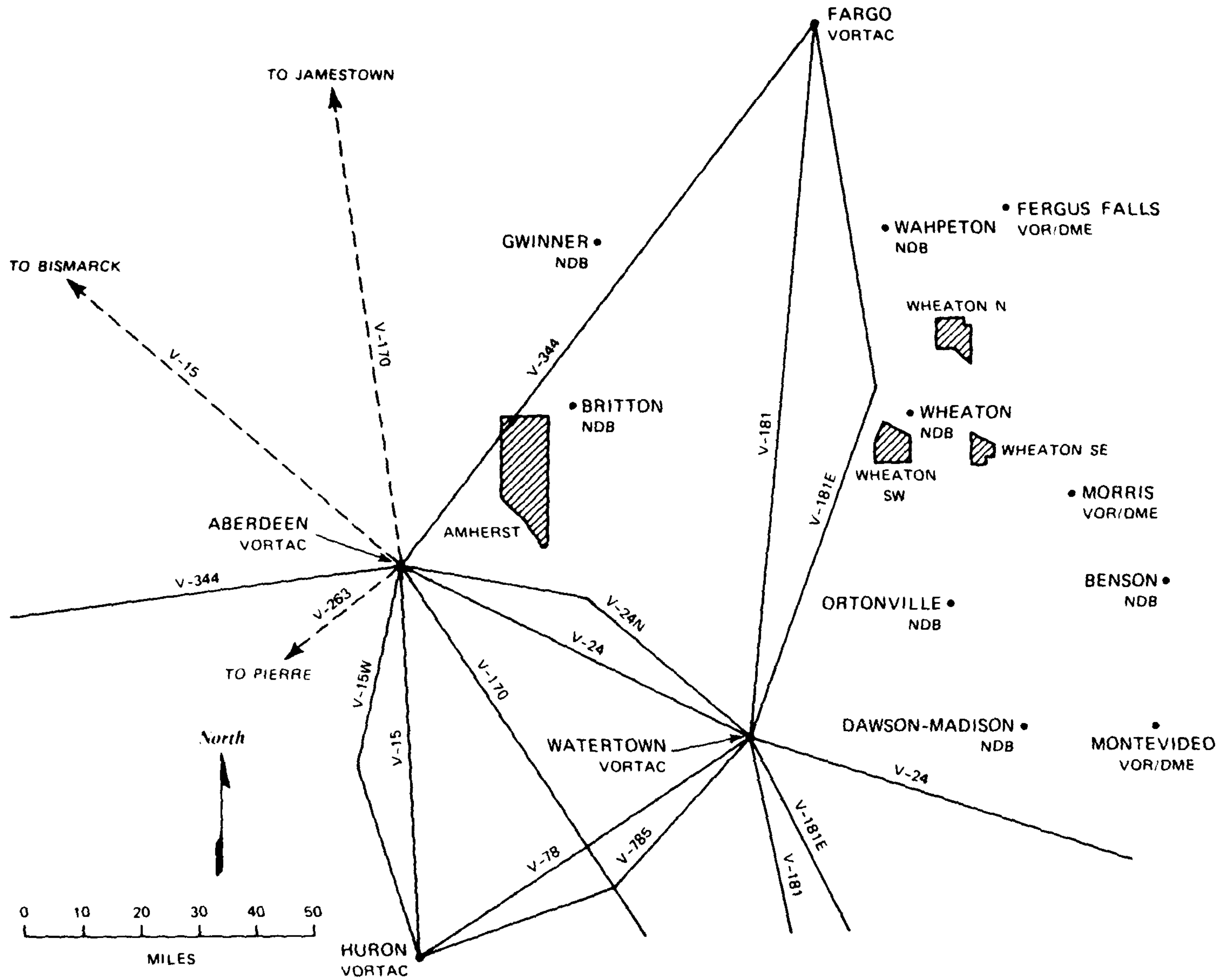


FIGURE C-8 AIR ROUTES IN THE VICINITY OF THE CENTRAL RADAR SYSTEM TRANSMITTER STUDY AREAS

that is, the harmonics of the radar may affect the receiver. The interference manifests itself by deviation of the VOR receiver's indicator needle, so that false bearings are obtained. Abel described two investigative measurement flight sequences. In the first, an aircraft leased by MITRE was flown along radials from the ERS site toward each of several VORs while the ERS transmitted on various permitted frequencies ranging from the sixth to the tenth subharmonics of the VORs involved. (Fifth subharmonics for the VORs in the vicinity of the ERS are at frequencies in band F, which was above the capability of the ERS.) MITRE found that the ERS caused oscillations of the indicating needle greater than $\pm$ 2° (or other false bearing readings) out to a maximum distance of 24 miles from the ERS transmit site.

The FAA conducted the next measurements, using its own instrumented aircraft. It flew three 360° orbits around the ERS at a range of about 17 miles and an altitude of 5,000 ft while the ERS transmitted on frequencies as far as 8 kHz below the sixth subharmonic of a VOR about 45 miles away. The FAA determined that out-of-tolerance course errors (greater than 3°) occurred at a number of azimuths, generally in front of the radar. In another flight, the FAA followed a route directly away from a VOR about 60 miles from the ERS, approaching the ERS from behind and passing within about 6 miles of it. The ERS was transmitting on a frequency 1.67 kHz below the sixth subharmonic of the VOR. Course errors were less than 1° until the aircraft was about 8 miles from (and behind) the ERS. Course errors then became greater than 3° until the aircraft passed essentially into the region in front of the radar; there, the errors became so large that the VOR signal was unusable at distances out to about 26 miles. On yet another flight, the FAA followed a route that approached within about 25 miles of and essentially in front of the ERS while the ERS was transmitting on the sixth subharmonic of the VOR in use. No interference was noted in that case.

The Maine VORs did not have the additional distance-measuring capability that the midwest VORTAC and VOR/DMEs have, and so the experience obtained at the ERS has no bearing on the interference to be expected in aircraft using equipment that receives the DME's UHF signals. The airborne DME may also be susceptible to the radar's harmonics, but no theoretical study or measurement is known to have treated this subject.

C.3.1.2.5.2.3 Probable Effects near the CRS Transmit Site

The map in Figure C-8 shows the transmitter-site study areas and their relationships to the Low Altitude Federal Airways between the local VORTACs. The map also indicates the locations of several airports served by VOR/DME equipment and by NDBs, but it does not show the routes that would be followed by aircraft using these airports.

From ERS experience, the radar can produce interference when it transmits on or very near the sixth subharmonic of a local VOR's frequency. The region in which this form of interference may occur extends about 26 miles "in front of" the radar, and about 10 miles "behind" it. In the case of the CRS, having four arrays, the possible sixth-subharmonic interference region "in front of" the radar is a 240° arc centered approximately due south and having a radius of about 26 miles; the corresponding region "behind" the radar is a 120° arc centered approximately due north and having a radius of about 10 miles.

Given the uncertainty about the eventual location of the CRS transmit site within one of these study areas, it is not yet possible to indicate on the map precisely the region in which the radar could be expected to produce interference with airborne VOR receivers. We can, however, show on Figure C-8 where the region would be if the radar were to be placed in the southeast corner of the Amherst study area. The shape and orientation of the region would remain the same for other locations of the radar transmitter.

Because this radar transmitter, unlike the ERS, will include band F (22.25-28.00 MHz) in addition to the others, interference could also occur when the radar transmits on the VORs' fifth subharmonic. The distances from the radar at which fifth-harmonic interference would occur could be predicted using broad assumptions regarding the radar transmitter output power at the harmonic frequencies and the gain and pattern of the transmit array at these harmonic frequencies (far removed from the radar's intended operating frequencies). Such assumptions, however, could easily be in error by a factor of 10 dB, and in predicting distances at which an interference effect will take place, a 10-dB error translates into a multiplying (or dividing) factor of about three in a predicted distance. Knowing, from the experience with the ERS, that such interference can occur, the Air Force could include both the fifth and sixth subharmonics of the nearby VORs in the list of forbidden transmit frequencies. Alternatively, the FAA could choose to change VOR frequencies so that their subharmonics would not even be used by the radar. The Air Force would cooperate with the FAA in determining the necessity and nature of any mitigation measures. The Air Force would also help by participating in FAA test flights designed to determine whether interference exists initially or following any mitigating measures.

C. 3.1.2.5.3 Non-Directional Beacons

A number of airports in the area are served by NDBs (see the map in Figure C-8). These NDBs are also sometimes known as compass locators and are probably the simplest radio aid to air navigation. Each NDB broadcasts omnidirectionally a coded identifying signal on a frequency in the 200- to 1,600-kHz band. The aircraft carries a direction-finding system, by which it can determine the direction from the plane to the

beacon. The NDB's antenna pattern includes a vertically directed null, so that when an aircraft passes directly overhead, there is a sharp decrease in signal strength; this provides the pilot with a definite fix on his position.

We do not know whether any tests have been conducted specifically to determine the effect of the OTH-B signal on the airborne direction finding receivers. However, the effects of the OTH-B signal would be very similar to those that would be experienced when a plane using an NDB signal passes close to any large HF transmitting system, such as those used by Voice of America and other users of the International Broadcast band. The situation would not be unique to the OTH-B radar.

C.3.2 Hazard Effects

This section discusses the potential effects of the OTH-B electromagnetic fields on equipment other than telecommunication systems. They are termed "hazard effects" because they describe three potentially dangerous situations that high-amplitude RF fields can cause under certain circumstances: (1) interference with the normal operation of implanted cardiac pacemakers, (2) accidental detonation of electro-explosive devices (EEDs), and (3) ignition of liquid fuels as they are being handled. Besides pacemakers, other implanted or attachable medical prosthetic devices exist, but they are principally in the developmental or prototype stage, and little information is available on their susceptibility to interference. These newer implantable devices are expected to have the same resistance to interference as modern pacemakers (Toler, 1982).

C.3.2.1 Cardiac Pacemakers

Cardiac pacemakers are potentially subject to EMI, thus it is possible that the OTH-B radar could affect pacemaker owners in its vicinity in the air or on the ground. Whether the OTH-B will affect a pacemaker depends on the susceptibility of the individual device and on the level of the OTH-B signal that reaches it. Although very few directly applicable susceptibility data are available from which to make exact predictions of the hazardous regions for a pacemaker owner, existing data suggest that the region is quite small and well within the proposed exclusion fence. The likelihood is very small that a pacemaker owner, either on the ground or in the air, would enter a potentially dangerous region or could remain there long enough to be affected. Thus, the possibility of interference is remote.

C.3.2.1.1 Background

The heart can be considered to be an electrically operated pump. It is a set of muscles that contract rhythmically in response to a periodic electrical impulse that originates naturally in a certain portion of the cardiac tissue. Some people who suffer impaired

operation of that natural pacemaker or of the conducting paths in the cardiac tissue rely on an artificial pacemaker, which supplies the electrical signal to make the heart beat when it should. Hundreds of thousands of people in the United States have pacemakers.

Four general types of cardiac pacemakers are employed, but by far the most common (80 to 90% of the pacemakers in use) is the R-wave-inhibited type. The R-wave-inhibited (synchronous) pacemaker supplies a pulse only on demand (i.e., when the heart requires it) and is often called a demand pacemaker. It senses the naturally occurring electrical signal of the main pumping action of the heart. If that fails to occur when it should, the pacemaker supplies the signal to trigger the heart's action. Although R-wave-inhibited pacemakers are generally more susceptible to EMI than the other types are, great progress has been made in recent years in reducing that susceptibility.

Pacemakers do not fail permanently when exposed to strong RF fields; instead, if the field is sufficiently intense, they may exhibit one of four types of dysfunction, of which the most common (for a synchronous pacemaker) is termed "reversion." This means that the pacemaker reverts to a benign fixed rate; it is designed to respond to RF by becoming, for the time being, an asynchronous pacemaker. Reversion is not always even considered a form of dysfunction. In fact, for purposes of monitoring the pacemaker's fixed rate (and thus the battery condition), a pacemaker owner frequently will deliberately cause his pacemaker to assume that condition.

C.3.2.1.2 Susceptibility to RF Fields

Most available data on the susceptibility of pacemakers have been developed at radio frequencies well above the HF band or at the AC power frequencies of 50 Hz, 60 Hz, and 400 Hz. The AC power frequencies were chosen for experiments because exposure to them is virtually unavoidable; everyone is exposed daily to fields or to physical contact with devices radiating at these power frequencies. At RF, a pulse-modulated 450-MHz signal "was selected as a compromise frequency that represents good body penetration and has been used by expert personnel in the field" (AAMI, 1975). Between 400 Hz and 450 MHz is a very large frequency range on which very few data have been published; measurements in that range are conducted only for special purposes, such as when the safety of pacemaker owners in the vicinity of some specific device or system is of concern.

The modulation of the RF field largely dictates whether and how a field will affect a pacemaker. Pulse modulation is the form of modulation most likely to affect a pacemaker, since the pacemaker is designed to sense electrical pulses, and a threshold of field intensity exists above which a given pacemaker will react to external RF pulses. According to Denny et al. (1977), at low PRFs (less than 10 pps) an R-wave-inhibited pacemaker is likely to misinterpret such pulses as the heart's

electrical activity and to become inhibited. At higher PRFs, the pacemaker is more likely to revert to asynchronous operation. Long-term inhibition (for durations greater than about five normal heartbeats) may constitute a health hazard for some owners, whereas reversion to fixed-rate pacing is less serious. One writer has stated that "frequency or phase modulation does not affect the pacemaker" (Schlentz, 1975). The OTH-B's modulation is a form of frequency modulation.

Although considerable research was conducted and many papers were published on pacemaker susceptibility to electromagnetic fields in the middle and late 1970s, this activity has greatly decreased. The principal reasons are that the Association for the Advancement of Medical Instrumentation (AAMI) developed a draft pacemaker susceptibility standard in 1975 (AAMI, 1975) and, in accordance with that draft standard, the pacemakers now being marketed are capable of unaffected operation in 450-MHz pulsed field strengths in excess of 200 V/m. (This implies that they would also almost certainly be capable of unaffected operation in a frequency-modulated field of 200 V/m.) That 1975 draft standard also required that the pacemaker be unaffected by CW (unmodulated) power-frequency signals directly coupled to the pacer at a 100-mV level. Susceptibility testing has now become routine, the Biomedical Research Division of the Engineering Experiment Station of Georgia Institute of Technology conducts that work for all but one of the major U.S. manufacturers, as well as for many of the major foreign manufacturers (Toler, 1982).

A later (November 1981) draft version of the AAMI pacemaker standard describes various performance tests, but all references to EMI susceptibility testing have been dropped. According to a cochairman of the AAMI pacemaker committee, this was done for two reasons. One was to make the U.S. standard more similar to an international standard so as to facilitate trade. The other reason was that the committee believed that a rigid electromagnetic compatibility standard could encourage manufacturers to produce pacemakers with EMI susceptibility no better than the minimum requirements of the standard (Flink, 1982). Mr. Flink agrees that the modern pacemakers are almost invulnerable to EMI.

Susceptibility levels, based on pulsed 450-MHz tests in August 1975, were published by Mitchell and Hurt (1976). That report states that the susceptibility levels (ranging from 4 V/m to more than 260 V/m) "are believed most representative of the current state of technology" (for 1975). The report also states that "if pacemakers were designed and tested to be compatible with the minimum E-field level, viz 200 V/m, associated with the unrestricted 10 mW/cm^2 personnel exposure level, potential EMI situations would be substantially reduced or effectively eliminated." Such a 200-V/m testing level, described in the 1975 standard prepared by the AAMI for the FDA, is now in general use. Schlentz et al. (1976) had shown that results of tests with the pacemaker immersed in saline solution to simulate body tissue were entirely equivalent at 450 MHz to results using implanted pacemakers.

The field strengths are defined and measured in the air outside the body or the saline solution. With the pacemaker submerged in the tank of saline solution, its catheter is aligned for maximum coupling with the electromagnetic field. Testing is to be done at, but not necessarily above, 200 V/m within 50 MHz of 450 MHz and at pulse repetition frequencies of 125% $\pm$ 10% of the basic rate of the pacemaker.

The only known measurements that indicate the susceptibility of pacemakers to RF fields in the HF band were conducted by the Air Force in 1977 (Hardy, 1979). In addition to pulsed signals at other frequencies, Hardy worked with a CW signal at 26 MHz, which would probably be very similar to the OTH-B linear FM/CW signal. Hardy's pacemakers were immersed in saline solution, which is also the method recommended in the 1975 standard and currently used by workers at Georgia Institute of Technology. Hardy reported on 26-MHz CW measurements using 30 pacemakers, of which 17 were unaffected by fields as high as 850 V/m--the maximum field available from the test system. The susceptibility thresholds of the other pacemakers ranged from 230 V/m to 850 V/m.

Both Mitchell (1978) and Denny (1978) suggested that the manufacturers were then probably meeting the 200-V/m level in their newer models. The 1977 measurements reported by Hardy in 1979 indicated that many were not susceptible to 450-MHz pulsed signals with levels as high as 330 V/m. Denny stated in 1978 that the threshold for most of the newly released pacemakers was above 300 V/m. Toler believed that none of the pacemakers being released by 1982 were susceptible to pulsed fields of 200 V/m.

Manufacturers contacted in an informal 1978 survey for the EIS for the PAVE PAWS (420- to 450-MHz) radar at Beale AFB stated that their newer pacemakers met the 1975 AAMI standard, and one manufacturer said that the manual for a particular model stated that it had been tested to 295 V/m.

By now (1986), probably none of the older pacemakers described in the literature of about 10 years ago would still be functioning; thus the susceptibility thresholds of the pacemakers currently in use is probably quite high. The reason for the rapid replacement of the older pacemakers with the newer ones is that an entirely new pacemaker must be implanted when the battery becomes exhausted; the physician then has an opportunity to implant a pacemaker less susceptible to EMI. When the mercury cell was the only type of battery used, pacemaker replacement was necessary about every 2 to 3 years; lithium iodide batteries last 6 to 8 years or more and are now essentially the only type used.

C.3.2.1.3 Susceptibility to OTH-B

Pacemakers are apparently not particularly susceptible to signals in the HF band. Because the OTH-B signal is essentially continuous (and not pulsed), the pacemaker does not confuse it with the naturally occurring electrical signals that the pacemaker is designed to sense. The

data available suggest that modern pacemakers would be affected by OTH-B fields only if the fields were well over 200 V/m. The curves shown on Figures B-5 through B-10 can be used to define a "safe" distance; beyond that distance, fields exceeding 200 V/m will not exist. Because more than one-half of Hardy's pacemakers were unaffected at 850 V/m and none were affected by fields as low as 200 V/m, the 200-V/m standard results in a very conservative estimate of safe distance.

At ground level in front of the radar, fields will fall below 200 V/m at a distance of about 1,300 ft from the center of the array. Section B.6 of Appendix B indicates that fields of 200 V/m will not exist at all behind the array. If the exclusion fence were located about 4,000 ft in front of each array, as shown in Figure B-11, the casual pacemaker owner approaching the radar would not be subjected to fields exceeding about 45 V/m, and so the radar should present no hazard.

In the sky in front of the radar, on the axis of the main beam, the fields would fall below 200 V/m at a slant range of about 1,300 ft. The main beam axis at this distance is at a height of about 400 ft; the horizontal beamwidth is about 200 ft, and the beam shifts horizontally from time to time. Above or below the 400-ft height or outside the nonstationary 200-ft wide beam, the field would be lower. This region of airspace is at a horizontal distance of just over 1,100 ft from the array and is above the land enclosed by the exclusion fence as suggested in Figure B-11; thus a pacemaker owner is highly unlikely to enter this small piece of airspace or to be able to remain in it for long.

Although operation of the radar could not be considered to constitute a hazard to pacemaker owners, the Air Force will request that the FAA publish an appropriate Notice to Airmen (NOTAM) warning fliers not to approach the radar too closely. Such NOTAMs have been published for other Air Force radars.

C.3.2.2 Fuel Handling

The military has long been concerned over the possibility that high-powered radars (such as those on an aircraft carrier) could ignite volatile fuels as they are transferred. Ignition would result if the high RF fields caused a spark across a gap in a fuel-air mixture that had certain proportions. Researchers have determined the DC spark energy required to ignite fuel; according to Air Force Technical Manual T.O. 31Z-10-4 (1971), "The amount of RF voltage required to break down a similar gap is unknown but is believed, until proven otherwise, to be approximately the same as the dc-voltage value." For fuel handling near a radar, "a peak power density of 5 W/cm^2 (5,000 mW/cm^2) or less can be considered safe."

For OTH-B, which would not pulse like a typical radar, but would operate continuously, the "peak" power density and the average power density are synonymous, providing that the average is taken over a time duration no greater than the dwell time that the radar's beam is directed

toward any given sector. Because any gap-breakdown effect would take place in milliseconds, or possibly microseconds, our concern must be with the radar's peak power density rather than with the long-term average power density used in Appendix B. There, the averaging considers that a given array's beam is equally likely to be directed toward any one of the array's eight 7.5° surveillance sectors. Table B-2 and Figures B-5 through B-10 show that the "peak" OTH-B power density, even in the near-field column, never exceeds about 258 mW/cm^2, which is a factor of almost 20 lower than the maximum safe power density of 5,000 mW/cm^2.

The OTH-B radar system will not pose a hazard to existing or planned fuel-handling operations.

C.3.2.3 Electroexplosive Devices

C.3.2.3.1 Types of EEDs

EEDs are used to activate secondary explosive charges, to ignite propellant systems, and to actuate electroexplosive switches. A common electric blasting cap is one form of EED. EEDs are used in aircraft systems to jettison flares and wing tanks while the aircraft is in flight, to release externally carried missiles, and, in some aircraft, to activate ejection seats. Still other applications exist, and the use of EEDs on modern military aircraft is common. The following are the four basic types of EEDs, actuation mechanisms, and uses (Hovan, 1978):

- Exploding bridgewire--This type requires a high-energy capacitive discharge pulse to explode bridgewire.

- Normal bridgewire--An explosive mix is glued to the bridgewire; electrical current heats the bridgewire, detonating the adhesive primer.

- Composition mix--This type uses conductive explosive mix; the current passes through the mix, igniting it.

- Carbon bridge type--This type is used internally in 3 or 4 weapons systems and in 20-mm cartridge primers.

All EEDs are ignited electrically and hence are subject to accidental ignition from the following causes:

- Lightning discharge--Lightning protective systems normally preclude the inadvertent ignition of EEDs by direct lightning strikes.

- Static electricity discharge--This is a hazard mainly for ground operations.

- Stray energy, such as transients and other forms of induced conducted energy, from other on-board electrical equipment.

- Radiated fields from RF emitters--If the RF field is strong enough, it can induce currents that will cause the EED to fire.

C.3.2.3.2 Electromagnetic Field Safety Standards for EEDs

EEDs are susceptible to ignition by exposure to radiated fields. The degree of susceptibility depends on many variables: the safe no-fire threshold of the EED, the ability of the EED leads to capture RF energy, the frequency and power density of the RF energy, and the condition of exposure of the EED--whether contained in a shielded cannister, mounted inside an aircraft with shielding provided by the skin of the aircraft, or exposed to the environment with no shielding present.

Although we are aware of the potential hazard to EEDs such as blasting caps,

> "From a practical standpoint, the possibility of a premature explosion due to RF energy is extremely remote. This has been demonstrated by numerous tests on representative transmitting equipment, and it is confirmed by many years of experience. The annual consumption of electric blasting caps is well over 100 million, and they are used in every section of the country. Yet there have been only two authenticated cases of a cap being accidentally fired by radio. Both these were caused by amplitude-modulated (AM) transmitters operating in the low frequency range (540-1600 kilocycles) with horizontal antennas" (State of Maine, 1976).

C.3.2.3.2.1 The Air Force Standard for Safe Exposure Limits

The Air Force safe exposure criterion is expressed either as a safe average power density, in W/m^2, or as a safe separation distance. As the distance, d, between an EED and the RF transmitter is increased, the power density at the EED decreases at least as rapidly as $1/d^2$.

The safe separation distances specified by the current version of AF Regulation AF 127-100, Explosive Safety Standards (USAF, 1983) are said to be based on a worst-case situation--that is, on the most sensitive EED currently in inventory, unshielded, and having leads or circuitry that could inadvertently be formed into a resonant antenna. The criteria apply generally to critical areas involving explosives assembly, disassembly, testing, loading, and unloading operations and are based on the safe, no-fire threshold of the EED. This is intended to be a very conservative safety threshold, and exceeding it does not imply that the EED will fire. The actual firing threshold of the EED may be several orders of magnitude above the safe no-fire threshold.

Table C-5 summarizes the AF Regulation 127-100 criteria for safe power flux density exposure for EEDs in several configurations. All safe exposure limits are given in terms of average power density in the 2- to 48.5-MHz frequency range.

Table C-5

SAFE EXPOSURE LIMITS FOR EEDs AT OTH-B FREQUENCIES

Exposure or Storage Condition for EED	Average Power Density W/m^2	mW/cm^2
EEDs in exposed condition (also applies for any "unknown worst case" situation).	0.01	0.001
EEDs in storage or transport, in metal containers, leads shorted	100	10
EEDs in storage or transport, in nonmetallic containers, leads shorted	0.1	0.01
Aircraft parked or taxiing with externally loaded weapons	1.0	0.1
Aircraft in flight with externally loaded weapons, or shipment of EEDs inside cargo aircraft	100	10
Leadless EEDs in original shipping configuration	(No maximum power density; minimum distance; 10 ft)	

Source: USAF, 1983.

The safe-distance predictions in this subsection are based on estimates of ground-wave power density, which themselves are based on estimates of the ground conductivity in the transmit study areas. A relatively high ground conductivity based on "marsh land" was used (Sailors et al., 1983), which may result in predictions of high power density at greater distances (Sailors et al., 1983) than will actually occur, and therefore in very large regions where transporting, storing, and/or handling EEDs are not guaranteed to be safe. The safe separation distances obtained through this extremely conservative approach are greater than would be found using lower, but still reasonable values for the soil conductivity in the power density predictions.

Figure C-9, taken from the plots of Figures B-5 through B-10 of Appendix B, compares some safe exposure limits with estimated OTH-B power densities that could occur in the vicinity of the radar. The ground-wave power densities here were calculated using an assumed ground conductivity that ranged from about 0.05 S/m at the lowest band to about 0.07 S/m at the highest band. Lower assumed ground conductivity would yield lower power density at a given distance. If the ground conductivity were known precisely, such curves would allow the accurate determination of the corresponding safe exposure distances. The sky-wave curve is the same for all six bands. The ground-wave curve differs from band to band, however. The two higher frequency bands (E and F) initially have a greater ground-wave power density because they are both vertically polarized, in contrast to the 45° polarization of the other bands. Because higher-frequency power density falls off more rapidly with distance than does that of the lower frequency bands, the power density of the lower frequency bands is greater at the greater distances. Thus, for a specific ground-wave power density, the most conservative approach is to consider the band that provides the greatest safe distance for that power density.

Curves are provided for the regions in front of the radar and behind it. The "front" of the radar is a 240° arc centered approximately due south; "behind" is everywhere else. Although the uppermost curve is labeled sky wave, the power densities there are simply the main beam power densities; if there were any mountain tops to be brushed by the main beam, that upper curve would be more applicable than the ground-wave curve.

The figure indicates that OTH-B presents no hazard to EEDs stored or being transported in metal containers at ground level at distances beyond about 1,300 ft from the array center, where bands E and F predominate. So far as is known, only military aircraft are likely to be equipped with EEDs. Aircraft in flight that carry or are equipped with EED, would be beyond the hazardous area if they were at a slant range of more than about 1,300 ft from the front of the radar. The NOTAM mentioned in Section C.3.2.1.3 will warn fliers against approaching the radar.

EEDs stored or being transported at ground level in nonmetal containers would be safe at distances greater than roughly 2.3 miles from the front of the radar or about 3,000 ft behind it.

Exposed EEDs, such as blasting caps being handled in preparation for a blasting operation, would be safe if removed to about 4 miles. If the ground conductivity is not as high as our estimate, the safe distance requirements would decrease.

Ground conductivity measurements would permit more accurate estimates of the ground-wave power density, and therefore more accurate determination of the safe separation distances.

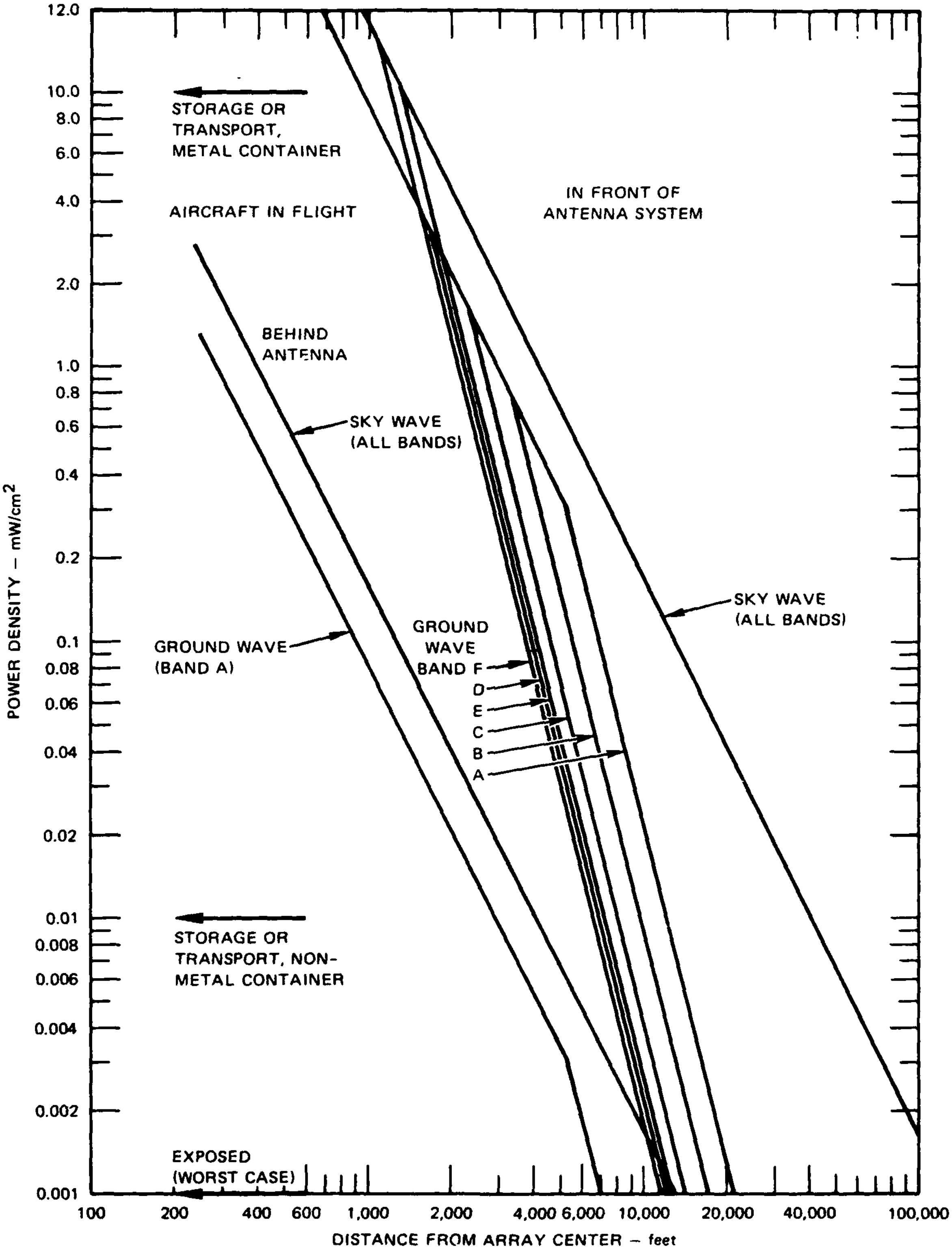


FIGURE C-9 OTH-B POWER DENSITIES AND SOME SAFE EXPOSURE LIMITS FOR EEDs

C.3.2.3.2.2 Explosives Manufacturers' Recommendations for Blasting Caps

The use and handling of electric blasting caps are specifically addressed in a publication by the Institute of Makers of Explosives (1981). The publication does not provide safe exposure limits in terms of power densities, but rather recommends safe distances from common emitters of RFR; in some cases the distance is given as a function of transmitter power or effective radiated power (the product of the transmitter power and the antenna gain). The evaluation that most closely approximates the OTH-B situation is a curve of "recommended distances from transmitters up to 30 MHz (excluding AM broadcast)" and applicable to "International Broadcast Transmitters in the 10-25 MHz range." Such transmitting systems, including the OTH-B system, are intended to launch a sky wave; ground-wave power is an unavoidable by-product. The curve therefore shows the safe distance as a function of the power that the transmitter puts into the antenna, not as a function of the power that the antenna array radiates in the sky wave. For simplication, the manufacturers' safe-distance curves do not take differences in ground conductivity into account, and appear to be conservatively based on the assumption of a very high conductivity. If we use a transmit power of 1.2 MW, the safe region would appear to begin at about 90,000 ft (17 miles), which would agree with the Air Force standard based on power-density estimates made using an extremely high ground conductivity.

C.3.2.3.3 Safe Regions Near the CRS Transmit Site

When the actual location for the transmit site has been selected, and when ground conductivity has been measured, it will be possible to determine more precisely the safe distances mentioned in Section C.3.2.3.2 related to the specific terrain features such as roads and buildings at the selected site. The Air Force will then notify all affected land owners and state and local government offices so that they can take any actions, such as making notifications or posting, that they deem appropriate.

C.4 References

AAMI (Association for the Advancement of Medical Instrumentation) (1975). "Labeling Requirements, Performance Requirements, and Terminology for Implantable Artificial Cardiac Pacemakers," Draft Standard, FDA Contract No. 223-74-5083, Association for the Advancement of Medical Instrumentation; Arlington, Virginia (August 1975).

Abel, W.G. (1980a). "AFCC Field Intensity Measurements for ERS RF Compatibility Test Objective," MITRE Technical Report MTR-8215, Project 4140, The MITRE Corporation, Bedford, Massachusetts.

Abel, W.G. (1981b). "Final Report on the ERS RF Compatibility Test Objective," ESD-TR-81-258, Project No. 4140, The MITRE Corporation, Bedford, Massachusetts.

Abel, W.G. (1980b). "Possible ERS Radiation Safety Hazards to Aircraft in Flight," MITRE Memo No. D81-M-6057 to D.J. Marino.

Bayer, R.E., Lt. Col., USAF Office of Legislative Liaison, (1981). Letter dated October 24, 1980, to Rep. James D. Santini, published in Review of International Broadcasting, p. 35.

C.C.I.R. (International Radio Consultative Committee) (1964). "Report 322, World Distribution and Characteristics of Atmospheric Radio Noise," International Telecommunication Union, Geneva, Switzerland.

C.C.I.R. (International Radio Consultative Committee) (1976). "Report 258-2, Man-Made Noise," International Telecommunication Union, Geneva, Switzerland.

Crippen, L.J. (1970). "Statistical Parameters of Radio Noise," 1970 IEEE Regional Electromagnetic Compatibility Symposium Record, 70C64, San Antonio, Texas.

Denny, H.W. (1978). Georgia Institute of Technology, personal communication.

Denny, H.W., B.M. Jenkins, and J.C. Toler (1977). "Behavior of Cardiac Pacemakers in Pulsed RF Fields," Proceedings of the 1977 IEEE International Symposium on Electromagnetic Compatibility, pp. 272-277.

Duff, W.G. and D.R.J. White (1972). "Volume 5 of a Handbook Series on Electromagnetic Interference and Compatibility, EMI Prediction and Analysis Techniques," Don White Consultants, Inc., Germantown, Maryland, pp 6.14-66.41.

FAA (Federal Aviation Administration) (1968). "VOR/VORTAC Siting Criteria," Handbook 6700.11.

Flink, R.C. (1982). Cochairman, Association for the Advancement of Medical Instrumentation (AAMI) Pacemaker Committee, personal communication.

Hardy, K.A. (1979). "Measured Effects of 450-, 350-, and 250-MHz Pulsed and 26-MHz CW Radiofrequency Fields on Cardiac Pacemakers," Report SAM-TR-79-20, USAF School of Aerospace Medicine, Aerospace Medical Division, Brooks Air Force Base, Texas.

Hovan, T. (1978). Aeronautical Systems Division, Wright-Patterson AFB, Ohio, personal communication.

Institute of Makers of Explosives (1981). "Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Electrical Blasting Caps," Publication No.20, IME, Washington DC, (September 1981).

Lyon, E., III (1982). Memorandum.

Mitchell, J.C. (1978). School of Aerospace Medicine, USAF, personal communication.

Mitchell, J.C. and W.D. Hurt (1976). "The Biological Significance of Radio Frequency Radiation Emission on Cardiac Pacemaker Performance," Report SAM-TR-76-4, USAF School of Aerospace Medicine, Aerospace Medical Division, Brooks Air Force Base, Texas.

Norton, K.A. (1941). "The Calculation of Ground Wave Field Intensity Over a Finitely Conducting Spherical Earth," Proceedings of the IRE, Vol. 29, pp. 623-639.

Sailors, D.B., W.K. Moision, and T.N. Roy (1983). "The New U.S. Army PROPHET Evaluation System (APES) Models," Technical Document 642, Interim Report, Naval Ocean Systems Center, San Diego, CA, (corrected).

Schlentz, R.J. (1975). "Electromagnetic Compatibility of Implanted Cardiac Pacemakers," Electromagnetic Compatibility 1975, Symposium Proceedings, 1st Symposium and Technical Exhibition on Electromagnetic Compatibility, Montreux, Switzerland.

Snyder, A.L. (1982). "System Specifications for the Over-The-Horizon Backscatter Operational Radar System," U.S. Air Force Electronics Systems Division, Hanscom Air Force Base, Massachusetts.

Spaulding, A.D. and J.S. Washburn (1985). "Atmospheric Radio Noise: Worldwide Levels and Other Characteristics," NTIA Report 85-173, U.S. Department of Commerce, National Telecommunications and Information Administration, Institute for Telecommunication Sciences, Boulder, CO.

State of Maine (1976). "Rules and Regulations for the Keeping, Dispensing or Transporting of Explosives," Department of Public Safety, State House, Augusta, Maine.

Stein, K.J. (1982). "Backscatter Radar Unit Enters Production Phase," Aviation Week and Space Technology, pp. 68-77.

Television and Cable Factbook (1983). Stations Volume, No. 51, published by Television Digest, Inc., Washington D.C.

Terman, F.E. (1943). Radio Engineers' Handbook, McGraw-Hill Book Co., New York, pp. 674-682.

Thomas, E.F. (1980). Deputy Program Director, OTH, North American Airspace Surveillance Systems Directorate letter dated May 20, 1980, to Larry Brookwell, published in Review of International Broadcasting, p. 3.

Toler, J.C. (1982). Biomedical Research Division, Engineering Experiment Station, Georgia Institute of Technology, personal communication.

USAF (1971). "Electromagnetic Radiation Hazards," Technical Manual T.O. 31Z-10-4, Air Force Communications Service (E-1 Standard), 1 August 1966 (Change 2, 1 June 1971).

USAF (1983). "Explosive Safety Standards," AF Regulation 127-100.

U. S. Department of Commerce (1986). N-O-A-A-, Sectional Aeronautical Chart, "Twin Cities."

Villard, O.G. Jr. (1980). "Over-the-Horizon or Ionospheric Radar," QST, pp. 39-43.

Appendix D

SIGNIFICANT ENVIRONMENTAL LAWS AND REGULATIONS PERTAINING TO THE NATURAL ENVIRONMENT AFFECTED BY THE OTH-B CENTRAL RADAR SYSTEM

Appendix D

SIGNIFICANT ENVIRONMENTAL LAWS AND REGULATIONS PERTAINING TO THE NATURAL ENVIRONMENT AFFECTED BY THE OTH-B CENTRAL RADAR SYSTEM

Regulatory Agency	Act/Regulation/Law	Regulated Resource/Activity	Description	Requirements
Federal				
U.S. Fish & Wildlife Service	Fish and Wildlife Coordination Act of 1958 (FWCA)	Streams	Requires that wildlife conservation be given equal consideration and be coordinated with other features of water resource development projects.	Section 662(a) requires consultation with U.S. Fish and Wildlife Service and the state wildlife agency whenever waters of any stream are modified for any purpose.
Army Corps of Engineers	Section 404, Federal Water Pollution Control Act of 1972, as amended in 1977 (Clean Water Act) (33 USC 1344)	Streams, Wetlands, Rivers	Controls discharge of dredged or fill material into waters of the United States.	Section 404(b)(1) of the Clean Water Act requires that the Corps of Engineers evaluate the proposed activity under Section 404(b)(1) guidelines prepared by EPA. The guidelines restrict discharge into an aquatic area if less environmentally damaging, practicable alternatives exist.
Army Corps of Engineers	Section 10, River and Harbors Act of 1899 (33 USC 403)	Navigable Waters	Prohibits the obstruction or alteration of navigable waters of the United States without a Corps of Engineer's Permit.	Section 10 requires that a permit obtained from the Corps if proposed activity would obstruct or alter navigable waters--defined as U.S. waters that are subject to ebb and flow of the tide shoreward to the mean high water mark and/or are used to transport interstate or foreign commerce.
U.S. Fish & Wildlife Service (FWS)	Section 7, Endangered Species Act of 1973, as amended (16 USC 1531)	Fish, Wildlife, Plants	Section 7(a) of act requires that Federal Agencies ensure that actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of endangered or threatened species or adversely affect or destroy habitats of species.	Informal consultation between Federal Agency and U.S. FWS must be undertaken if listed species or their habitats are believed to be present in area of proposed action. Preparation of biological assessment and formal consultation may be required.
U.S. Fish & Wildlife Service	EPA Administrator Decision Statement #4, Feb. 21, 1973	Wetlands Floodplains	Policy statement to protect wetlands from adverse dredge and fill practices.	

SIGNIFICANT ENVIRONMENTAL LAWS AND REGULATIONS PERTAINING TO THE NATURAL ENVIRONMENT AFFECTED BY THE OTH-B CENTRAL RADAR SYSTEM

Regulatory Agency	Act/Regulation/Law	Regulated Resource/ Activity	Description	Requirements
	Executive Order 11990 Protection of Wetlands, May 24, 1977; and Executive Order 11988, Floodplain Management, May 24, 1977	Wetlands	Avoid development in wetland or floodplain unless no practicable alternative exists, and then only after strong mitigation measures are developed.	
U.S. Fish & Wildlife Service	National Wildlife Refuge System, PL 95-469	Wildlife Refuges	Act allows public or private use of the natural resources of any wildlife area when the use contributes to or is related to the objectives of the National Wildlife Refuge System.	Section 29 requires permission be granted by U.S. FWS for right-of-way in a National Wildlife Refuge System Land when proposed activity is compatible with the major purpose for which such areas are established. Permission will not be granted if activity is not compatible.
Council on Environmental Quality (CEQ), Environmental Protection Agency (EPA)	National Environmental Act of 1969		Act establishes that environmental amenities and values be given appropriate consideration in decision-making, along with economic and technical considerations.	Section 1507.3 of CEQ regulations requires each Federal Agency to adopt procedures to implement NEPA in accordance with CEQ regulations. See AFR 19-2, "Environmental Impact Analysis Process" for internal AF procedure.
Environmental Protection Agency	Resource Conservation and Recovery Act of 1976 (RCRA) The Hazardous and Solid Waste Amendments of 1984	Underground Storage of Petroleum Products	Subtitle I provides for the development and implementation of a comprehensive regulatory program for underground storage tanks that contain petroleum and other regulated substances.	A notification form for each tank must be filed with the designated state or local regulatory agency within 30 days of installation. The tank design and installation must be in compliance with adopted federal, state, or local standards.
U.S. Department of the Interior (DOI), National Park Service	Wild and Scenic Rivers of 1968	Rivers	Act establishes procedures for protecting outstanding rivers in their "free flowing condition"; DOI prepares an inventory of rivers from which Congress may make designation.	Under Section 7 of the Act, different requirements apply to "designated" rivers, rivers "under study," and rivers identified in the inventory. Proponent should check with National Park Service to determine classification of rivers in proposed activity area.

SIGNIFICANT ENVIRONMENTAL LAWS AND REGULATIONS PERTAINING TO THE NATURAL ENVIRONMENT AFFECTED BY THE OTH-B CENTRAL RADAR SYSTEM

Regulatory Agency	Act/Regulation/Law	Regulated Resource/ Activity	Description	Requirements
U.S. Department of the Interior	Historic Sites, Building and Antiquities Act of 1935	Rivers, Streams	Federal Agencies are responsible for considering the existence and location of natural landmarks when assessing effects of their actions in the environment.	Proponent should check with National Park Service to determine if any sites on the National Registry of Natural Landmarks are in proposed area of activity. Environmental analysis should consider alternative plans.
U.S. Dept. of Agriculture, Soil Conservation Service	Farmland Protection Policy Act of 1981	Farmland	The Act defines four categories of important farmland that deserve protection.	The Act requires that Federal Agencies evaluate adverse effects of Federal programs on the preservation of farmland to consider alternative actions that could lessen the impact. The Act also requires that Federal programs be compatible with state, local, and private programs and policies to protect farmland.
Advisory Council on Historic Preservation	National Historic Preservation Act of 1966, as amended (16 USC 470)	Historic or Archaeologic Sites	The intent of the Act is to ensure that no significant archaeological or historical properties are irretrievably lost as a result of federally funded construction projects.	Section 106 requires that Federal Agencies take into account the effect of a federally funded, licensed, or assisted project on any historic or archaeological property listed or eligible for listing in the National Register.
	Section 401, Federal Water Pollution Control Act of 1972, as amended in 1977 (Clean Water Act) (33 USC)	Discharges to Navigable Waters	Certifies that any proposed discharge to navigable waters will not impair water quality.	Requires applicant for a Federal license or permit for any activity that may result in a discharge to navigable waters to provide the permitting agency with a certification, from the state in which the discharge originates, that this discharge will comply with the applicable provisions of Sections 301, 302, 303, 306, and 307 of the Clean Water Act.

SIGNIFICANT ENVIRONMENTAL LAWS AND REGULATIONS PERTAINING TO THE NATURAL ENVIRONMENT AFFECTED BY THE OTH-B CENTRAL RADAR SYSTEM

Regulatory Agency	Act/Regulation/Law	Regulated Resource/ Activity	Description	Requirements
Department of Natural Resources	Minnesota Statutes, Chapter 105 Division of Waters, Soils and Minerals	Construction of dams, alteration of shorelines and waterways, shoreland management and conservation, appropriation and use of waters, and establishment of lake levels	Charges the Division of Waters, Soils, and Minerals with the management and conservation of the state's water resources to promote public health safety, and welfare. Appropriation and use of surface and underground waters as well as any activity that changes the course current or cross-section of public waters are controlled by this division.	For domestic water use serving more than 25 persons, a permit must be obtained from the Commissioner of Natural Resources pursuant to Section 105.41. Section 105.42 specifies that a permit is required from the Commissioner for filling, excavating, or placing materials in or on the beds of public waters. For authority to establish and maintain levels on any public water, application must be made to the Commissioner according to Section 105.43. Under Section 105.485, proposed project must be reviewed to ensure compliance with local shoreland conservation ordinances.
Environmental Quality Board	Minnesota Statutes, Chapter 116D State Environmental Policy	Significant environmental impacts	Contains a declaration of the state's environmental policy and sets forth the responsibilities and actions of the state agencies for carrying out this policy. The state's environmental impact statement process is outlined.	Section 116D.04 requires that a detailed statement addressing environmental impacts, unavoidable adverse results, and alternatives to the proposed action be prepared and submitted to the state when there is potential for significant environmental effects. If the project meets the guidelines and regulations established by the Environmental Quality Board, an environmental impact statement may be required.
Department of Natural Resources	Minnesota Statutes, Chapter 104 Flood Plain Management	Floodplain management	State's policy regarding floodplain management is presented in this legislation. Management strategies and the Wild and Scenic Rivers Act are outlined.	Pursuant to Section 104.04, floodplain management ordinances must be adopted, administered, and enforced by local governmental units. A review of proposed actions must be performed to assess compliance with these ordinances.

SIGNIFICANT ENVIRONMENTAL LAWS AND REGULATIONS PERTAINING TO THE NATURAL ENVIRONMENT AFFECTED BY THE OTH-B CENTRAL RADAR SYSTEM

Regulatory Agency	Act/Regulation/Law	Regulated Resource/ Activity	Description	Requirements
Pollution Control Agency	Minnesota Statutes, Chapter 115 Water Pollution Control, Sanitary Districts, Water Pollution Control Act	Disposal system installation and operation; water pollution	Sets forth the duties of the Minnesota Pollution Control Agency, establishes bodies and laws for regional water pollution control, and outlines the classification of water supply and wastewater treatment facilities.	Sections 115.03 and 115.43 outline the duties of the Minnesota Pollution Control Agency, which requires that permits be issued to prevent, control, or abate water pollution and for the installation or operation of disposal systems. Counties and localities may also have jurisdiction over disposal systems.
Department of Natural Resources	Minnesota Statutes, Chapter 97, Section 97.488, Game and Fish, Protection of Threatened and Endangered Species	Wildlife, fish, plants	Prohibition, designation, study, management, and enforcement pertaining to threatened and endangered species are outlined in this law.	Project review by the Commissioner of Natural Resources is necessary to ensure the survival of threatened and endangered species, if these species or their habitats are present within the project area.
Department of Agriculture	Minnesota Statues, Section 17.8 - 17.9, State Agricultural Land Preservation and Conservation	Agricultural lands	Two main objectives of this legislation are: to determine, if possible, alternative methods or actions to the proposed project to avoid the loss of agricultural lands; ascertain whether the proposed action is more valuable than the agricultural lands it affects. If so, the Commissioner of Agriculture will be advised and will conduct a review.	The Commissioner of Agriculture must review the project if it is more than 10 acres in size and if the proposed action is deemed to be more valuable than the agricultural lands it is affecting.
Department of Agriculture	Minnesota Statutes, Chapter 40A Agricultural Land Preservation Program	Agricultural lands	Goals and methods of the state agricultural land preservation policy are outlined in the legislation. Agricultural land preservation plans are drawn up by the county. Certain lands may be designated as exclusive long-term agricultural use zones.	A review of the proposed project by the Environmental Quality Board in consultation with affected local governments must be performed to assure that the proposed action is in accordance with existing local and regional management plans. Certain public projects and assessments are explicitly prohibited in exclusive agricultural use zones.

SIGNIFICANT ENVIRONMENTAL LAWS AND REGULATIONS PERTAINING TO THE NATURAL ENVIRONMENT AFFECTED BY THE OTH-B CENTRAL RADAR SYSTEM

Regulatory Agency	Act/Regulation/Law	Regulated Resource/ Activity	Description	Requirements
Pollution Control Agency	Minnesota Rules, Pollution Control 4, Oil Storage Regulations	Above-ground oil storage	Regulations relating to the above-ground storage or keeping of oil and other liquid substances capable of polluting waters of the state.	Pursuant to WPC4, Section D, a permit must be issued with conditions prescribed to prevent pollution of any waters of the state. A permit is also needed by owners of a flammable liquid storage facility and must be certified by the Minnesota State Fire Marshal.
Pollution Control	Minnesota Statutes, Chapter 116, Pollution Control Agency Chapter 84, Order Granting Permit, Findings, Restrictions	Underground storage of fuel oil	Underground Storage Tank Act presented in sections 116.46-116.50 mandates a notification procedure for tanks and authorizes the regulatory agency to set interim standards for leak detection, reporting of releases and corrective action, closure, financial responsibility, and performance standards.	A notification form designed by the state must be completed for each underground storage tank. Under Sections 84.60 and 84.621, the conditions prohibiting the issuance of a permit for the underground storage of gas or liquid are specified.

A number of other state permits may need to be obtained, depending on the final project design. A partial list of these permits includes: utility crossings of public lands and waters (M.S. Section 84.415); aircraft operation in wilderness areas (M.S. Section 84.45); cutting and removal of timber (M.S. Section 90.151); air, solid waste and noise pollution (M.S. Sections 116.07 and 116.081); and connecting drains to highway drains (M.S. Section 160.20). In addition, various county and local permits and reviews may be required.

State - North Dakota

State Water Commission	North Dakota Statutes, Chapter 61-04, Appro-	Wells, water use, drainage alterations	Defines permit requirements and the application process for the beneficial use of surface waters of the state. Deinfes water rights associated with such permits.	Section 61-04-02 requires that a permit be obtained from the state engineer for the appropriation of water prior to construction. Immediately following the construction of any water retaining basin, the water user shall notify the state engineer of the location and storage capacity of the constructed works.

SIGNIFICANT ENVIRONMENTAL LAWS AND REGULATIONS PERTAINING TO THE NATURAL ENVIRONMENT AFFECTED BY THE OTH-B CENTRAL RADAR SYSTEM

Regulatory Agency	Act/Regulation/Law	Regulated Resource/ Activity	Description	Requirements
Local Water Resources Board	North Dakota Statutes, Chapter 61-16.1, Operation of Water Resources Districts	Water resources, dams, wetlands, drainage, diversion	Defines responsibilities of the Water Resources Board to include: encouragement of the retention of water on land and maintenance of the policy that upstream landowners and districts that artificially alter the hydrologic scheme share with downstream land owners the responsibility to manage and control such waters; full consideration of the downstream impacts in the planning of any surface water project; requirement for the appropriation of easements when projects will cause adverse impacts on lands of other landowners. Defines guidelines and procedures to be followed for the establishment of new drainage ditches.	Section 61-16.1-38 requires that a permit be obtained from state engineer prior to construction of any dike, dam, flood control basin, or storage basin capable of retaining or diverting more than 12.5 acre-feet of water. Section 61-16.1-41 requires that a permit be obtained from the state engineer prior to draining the water from a pond, slough, or lake that drains an area of 80 acres or more.
State Water Commission	North Dakota Statutes, Chapter 61-16.2, Floodplain Management	Floodplain Management	Describes definition and acceptable uses of land within floodplains of the state.	No explicit requirements.
Board of Drainage Commissioners	North Dakota Statutes, Chapter 61-21	Drainage ditch construction, alteration	Describes regulations and guidelines for procedures to be followed for the construction, maintenance, repair, extension, or other alteration of watercourses, ditches, or drains.	Guidelines for design and construction of drains, culverts, and bridges are established and requirements for public hearings by Board of Drainage Commissioners are specified in this chapter.
State Water Pollution Control Board	North Dakota Statutes, Chapter 61-28, Control, Prevention and Abatement of Surface Waters	Discharges to waters of state	Provides state water pollution control board with the power to control, prevent, and abate the pollution of the surface waters of the state and the authority to adopt, amend, or repeal rules, regulations, and standards for water quality in the state.	Section 61-28-06, prohibits the construction, installation, modification, or operation of any waste disposal system without plans and specifications previously approved by the State Department of Health and the State Water Commission.

SIGNIFICANT ENVIRONMENTAL LAWS AND REGULATIONS PERTAINING TO THE NATURAL ENVIRONMENT AFFECTED BY THE OTH-B CENTRAL RADAR SYSTEM

Regulatory Agency	Act/Regulation/Law	Regulated Resource/ Activity	Description	Requirements
State Board of Water Well Contractors	North Dakota Statutes, Chapter 43-35, Water Well Contractors	Well Construction	Establishes a state board of water well contractors to oversee the business of constructing water wells in order to protect the public welfare, health, and safety.	Requires that only state-certified contractors construct water wells in the state of North Dakota. Rules and regulations for well drilling and pump installation as set forth in this chapter must be complied with.
State Water Commission	North Dakota Statutes, Chapter 61-02, State Water Commission	Diversion and alteration of wetlands, ponds, streams, rivers	Establishes State Water Commission with the power and duty to maintain policies for water conservation, flood control, water management and development.	State water commission has full and complete power to investigate, regulate, and supervise any impoundments of water, diversion of waters, regulations of flood flow, construction of drainage ditches or alterations to existing channels and should be consulted prior to undertaking these mentioned activities.
State Board of Flood Irrigation	North Dakota Statutes, Chapter 61-12, Flood Irrigation Projects	Retention ponds, flood control dams, dikes	Establishes Board of Flood Irrigation to control and supervise the construction and maintenance of dams, gates, ditches, and canals for the purpose of controlling and regulating flood flows.	No explicit requirements
State Engineer	North Dakota Statutes, Chapter 61-15, Water Conservation	Filling of lakes, ponds	Promotes the conservation and maintenance of surface water bodies including dams, dikes, drainage ditches, and other structures.	Section 16-15-08 requires written consent from the state engineer prior to the draining of any lake or pond.
State Engineer	North Dakota Statutes, Chapter 61-20, Artesian Wells	Wells	Describes regulations that require conservation of water from artesian or flowing wells.	Section 16-20-02 requires that rules for drilling artesian wells set forth by the state engineer be complied with.
State Department of Health	North Dakota Regulation 23-29-01	Solid waste	Provides general regulations for the storage, collection, transportation, and disposal of solid wastes.	No explicit requirements.

Various county and local permits and reviews may also be required for the project.

SIGNIFICANT ENVIRONMENTAL LAWS AND REGULATIONS PERTAINING TO THE NATURAL ENVIRONMENT AFFECTED BY THE OTH-B CENTRAL RADAR SYSTEM

Regulatory Agency	Act/Regulation/Law	Regulated Resource/ Activity	Description	Requirements
<u>State - South Dakota</u>				
Department of Water and Natural Resources	South Dakota Codified Laws, Chapter 46-1, Definitions and General Provisions, and Chapter 46-2A, Administrative Procedure for Appropriation of Water	Appropriation of water, well construction, floodplain management, diversion	Establishes water as a property of the people and defines beneficial uses. Permitting and licensing procedures for water appropriation are outlined.	Pursuant to section 46-1-15 and 46-2A-9, a permit is required from the Water Management Board before waters of the state can be appropriated for any beneficial use. Water permits are not required for vested rights to surface water, water distribution systems diverting 18 gpm or less, and reasonable domestic use. A permit may be issued for flood control works if the conditions stated in Sections 46-2A-11 and 46-5-47 are met.
Department of Water and Natural Resources	South Dakota Codified Laws, Chapter 46-4, Dry-draw and Non-navigable Stream Dams, and Chapter 46-5, Appropriation of Water	Dam construction and removal, well construction, diversion	Rights and permits pertaining to dry-draw and nonnavigable stream dams are outlined in detail in Chapter 46-4. Chapter 46-5 details the technical specifications and rights associated with the appropriation of water.	According to Sections 46-6-1 and 46-5-8, a permit is required to construct a dam if more than 25 acre-ft will be impounded. An appropriation permit is required if water is to be conveyed by a water distribution system diverting more than 18 gpm pursuant to Sections 46-5-8.2 and 46-5-10. The permit may allow diversion from a designated source at one or more points within the area described in the permit (Section 46-5-13).
Department of Water ground- and Natural Resources	South Dakota Codified Laws, Chapter 46-6, Groundwater and Wells	Well construction and closure	Rights pertaining to groundwater withdrawal, the notification of well locations, rules and regulations governing large-capacity wells, well driller licensing, and well control and protection are presented in Chapter 46-6.	Section 46-6-3 specifies that waters of the state must be appropriated pursuant to Chapter 46-2A, which requires an appropriation permit to be issued. The Water Management Board requires that wells be constructed as specified to prevent waste under Sections 46-6-10 and 46-6-20. Plugging or other controls of abandoned wells are required and specified in Sections 46-6-18 and 46-6-20.

SIGNIFICANT ENVIRONMENTAL LAWS AND REGULATIONS PERTAINING TO THE NATURAL ENVIRONMENT AFFECTED BY THE OTH-B CENTRAL RADAR SYSTEM

Regulatory Agency	Act/Regulation/Law	Regulated Resource/ Activity	Description	Requirements
Department of Water and Natural Resources	South Dakota Codified Laws, Chapter 34A-2, Water Pollution	On-site sewage disposal systems	Powers and duties of the governmental unit responsible for controlling water pollution are presented in this chapter.	The Secretary of the Department of Water and Natural Resources may require the submission of plans and specifications for on-site disposal systems for review pursuant to Section 34A-2-29.
South Dakota Game, Fish, and Parks Dept.	South Dakota Codified Laws, Chapter 34A-8, Endangered and Threatened Species	Wildlife, fish, plants	Outlines policy and actions pertaining to the protection of threatened and endangered species within the state. An endangered species list for the State of South Dakota has been adopted.	The Secretary of the Game, Fish, and Parks Dept. must review the proposed action, in an effort to protect endangered or threatened species and their habitats within the project area.
Board of County Commissioners	South Dakota Codified Laws, Chapter 46A-10A, County Drainage	Drainage, diversion, wetlands	Details the establishment of county drainage commissions, directs the development of county drainage plans, and sets forth technical specifications for drain location, construction, and maintenance.	Section 46A-10A-30 gives the board power to adopt a permit system. A permit is specifically required for modification of a permitted drain or for use of an unrecorded water right. Other official controls, including ordinances, orders, and regulations, may be instituted by a board for drainage management. Pursuant to Section 46A-10A-59, a project petition describing the project in detail and assessing the impact on public property within the affected territory should be presented to the board. The board within each affected county should be consulted for specific review requirements.
Department of Water and Natural Resources	South Dakota Codified Laws, Chapter 284, Underground Storage	Underground storage	Authorizes the Board of Water Management to adopt rules pertaining to requirements for leak detection and control, record-keeping, reporting of releases and corrective action, closure, financial responsibility, and standards of performance for underground storage tanks.	Notification of an underground storage tank installation must be made to the regulatory agency pursuant to Section 2.

Appendix E

SUMMARY OF AESTHETIC RESOURCES AND IMPACTS FOR CENTRAL RADAR SYSTEM

Appendix E

SUMMARY OF AESTHETIC RESOURCES AND IMPACTS FOR CENTRAL RADAR SYSTEM

Study Area	Scenic Quality		Viewer Sensitivity		Impacts	
	Rating	Dominant Features	Rating	Viewing Points	Significance	Notes:
North Dakota						
Dahlen	Low to medium	Northern portion; agric. croplands, tributaries of Turtle River and Forest River; lower portion: numerous washes, rolling hills; low brush/grass; utility lines; isolated farm buildings.	Moderate	Central portion of study area within 1 mile of Dahlen; county road through middle of study area (east-west), state highway north-south through area.	Not significant	Hilly portions of study area would require cut and fill, which would result in higher visual contrasts that would have high significance if antennae site is within 2-3 miles of primary roads.
Goose River	Low to medium	Flat to gently sloping topography; Goose Creek and Beaver Creek and numerous tributaries/ small creeks provide undulating lines through landscape; small lakes in western portion of study area; tree breaks around fields; isolated agricultural buildings, utility lines.	Moderate	Communities of Logan Center, Elevator; highway 15 and county roads through study area.	Not significant	Project site in the central portion of study area would result in fewer visual contrasts with undulating line of creeks and drainage.
Galesburg	Low to moderate	Flat topography; agriculture cropland; wetland area and wildlife management preserve along western boundry; Elm River through study area; Goose River northwest section of study area; grain co-op silos, grain elevators; homestead building, tree breaks around fields.	Low to moderate	Communities of Clifford and Galesburg along eastern boundary of study area; county roads through study area.	Not significant	Project site in central portion of study area away from wetlands and creek would result in minimal visual contrasts.
Blanchard	Low	Flat agricultural cropland; Elm River through north-central portion of study area; Burlington Northern Railroad and highway bisecting study area north-south; clusters of trees.	Moderate	Highway 18 through study area; communities of Blanchard, Greenfield, Preston along highway.	Not significant	Project site 2-3 miles from state highway and farm communities would minimize impact sensitivity.

SUMMARY OF AESTHETIC RESOURCES AND IMPACTS FOR CENTRAL RADAR SYSTEM

Study Area	Scenic Quality		Viewer Sensitivity		Impacts	
	Rating	Dominant Features	Rating	Viewing Points	Significance	Notes:
Minnesota						
Thief River Falls	Moderate	Agricultural cropland; state highway 1 (northeast) flat topography; small blocks of forested land in eastern half of study area; Black River wetland area running north-south through study area; Prairie Pothole region, natural habitat for migratory birds; unpaved roads, utility lines.	Moderate	Highway 1 in northeast section of study area; Interstate 75, southwest section; county road through center section and along Black River; community of Carpenters Corner; numerous Wildlife Management areas, central and southern portion of study area (Pembia Wildlife Management area).	Not significant	Lower viewer sensitivity and visual contrasts in northwest portion of study area more than 3 miles from sensitive resource areas.
Wheaton N	Low	Flat topography; agricultural cropland; channelized water courses; tributaries of Fivemile creek; utility lines; tree breaks bordering fields.	Low to moderate	Highway 55 within 1 mile of northern boundary of study area; highway 9 east of study area; Interstate 75, 2 miles east of study area; Traverse Air field.	Not significant	No landscape features of high quality or scenic interest in study area; low visual contrast with existing elements.
Wheaton SE	Low	Flat topography; agricultural cropland; tributaries of Twelvemile creek; utility lines, county roads; small impoundment pond.	Low	Remotely located; more than 4 miles from major roads/highways.	Not significant	Low sensitivity and scenic quality.
Wheaton SW	Moderate	Relatively flat; predominantly agricultural croplands; numerous prairie pothole wetlands; Lake Traverse and Mud Lake adjacent to northwest portion of study area; native grasslands vegetation along wetland area provide variety in color, texture (state-listed species: Missouri Milk vetch, Wolf's Spikke rush); large trees forming tree breaks around croplands; isolated stands of trees.	Moderate	Highway 27 and Lake Traverse along northwest edge of study area; heavy use by resident and migrant waterfowl providing scenic recreational resources to motorists.	Not significant	Low sensitivity and visual contrasts in southeastern portion of study area; moderate sensitivity in northwest portion due to proximity to Lake Traverse and highway.

SUMMARY OF AESTHETIC RESOURCES AND IMPACTS FOR CENTRAL RADAR SYSTEM

Study Area	Scenic Quality		Viewer Sensitivity		Impacts	
	Rating	Dominant Features	Rating	Viewing Points	Significance	Notes:
South Dakota						
Amherst	Low to moderate	Topographic relief in southern portion of study area; Antelope Creek and small lakes; Burlington North RR across northern portion; utility lines.	Low to moderate	Communities of Amherst, Langford; county roads.	Not significant	Project site in north-central portion of study area would minimize impacts resulting from cut and fill (in southern portion of study area).

Appendix F

DISTRIBUTION LIST

Appendix F

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Congressional Delegation

Honorable James Abdnor
United States Senate
Washington, D.C. 20510-0001

Honorable Mark Andrews
United States Senate
Washington, D.C. 20510-0001

Honorable Rudy Boschwitz
United States Senate
Washington, D.C. 20510-0001

Honorable Quentin N. Burdick
United States Senate
Washington, D.C. 20510-0001

Honorable Thomas A. Daschle
House of Representatives
Washington, D.C. 20515-0001

Honorable Byron L. Dorgan
House of Representatives
Washington, D.C. 20515-0001

Honorable David Durenberger
United States Senate
Washington, D.C. 20510-0001

Mr. William J. Janklow
Governor of South Dakota
Pierre, SD 57501

Mr. Rudy Perpich
Governor of Minnesota
Suite 388
444 N. Capitol Street
Washington, D.C. 20001

Honorable Larry Pressler
United States Senate
Washington, D.C. 20510-0001

Mr. George A. Sinner
Governor of North Dakota
Bismarck, ND 58505

Honorable Arlan Stangeland
House of Representatives
Seventh District
Washington, D.C. 20515-0001

Honorable Vin Weber
House of Representatives
Second District
Washington, D.C. 20515-0001

Department of Defense

Eric Balzar
HQ AFOTEC BDM/OA
Kirtland AFB, NM 85117-7001

C. R. Boston
Oakridge National Lab
Oakridge, TN 37831

Lt. Col. John Burr
AFOMS/SGPR
Brooks AFB, TX 78235

Mr. John Mitchell
HQ USAFSAM/RZP
Brooks AFB, TX 78235

Mr. W. A. Nixon
HQ AFESC/DEVP
Tyndall AFB, FL 32403

ESD/SCO
Hanscom AFB, MA 01731

ESD/DE
Hanscom AFB, MA 01731

ESD/JAG
Hanscom AFB, MA 01731

ESD/PA
Hanscom AFB, MA 01731

HQ TAC/DRCD
Langley AFB, VA 23665

HQ TAC/DEE
Langley AFB, VA 23665

HQ TAC/LGK
Langley AFB, VA 23665

HQ AFSC/SDED
Andrews AFB
Washington, D.C. 20331

HQ AFSC/DEMV
Andrews AFB
Washington, D.C. 20331

HQ USAF/LEEVP
Bolling AFB
Washington, D.C. 20332-5000

HQ NORAD/NPD
Peterson AFB, CO 80914

HQ Space Cmd./DEPV
Peterson AFB, CO 80914

HQ SAC/DEP
Offutt AFB, NE 68113

2152 ISS
Grand Forks AFB, ND 58205-6346

321 SMW/DE
Grand Forks AFB, ND 58205-6346

U.S. Army Corps of Engineers
Omaha District
Attn: MRORE-P
6014 U.S. Post Office and Court
House
Omaha, NE 68102

<u>Federal, State, and Local Government Agencies</u>

Carl H. Altenbernd
Lake Agassiz Regional Council
321 North 4th
Fargo, ND 58103

Arnold Andersen
Chairman, Day County Commission
Route 1, Box 2
Bristol, SD 57219

Clifford Anderson
Division of Office of Planning
Planning and Review
Minnesota Pollution Control Agency
1935 W. County Rd. B2
Roseville, MN 55113

Mr. Gaylon Baker, Director
South Central Dakota
Regional Council
P.O. Box 903
Jamestown, ND 58501

Fred L. Ballou
Thief River Falls
Area Vacational Technical
Institute
Highway One East
Thief River Falls, MN 56701

Ronald L. Bell
Agassiz National Wildlife Refugee
RR 1
Middle River, MN 56737

Representative Charles Brown
Room 211
SOB
St. Paul, MN 55155

Mr. Maurice Chandler, Coordination
Single Point of Contact
Intergovernmental Review
Minnesota State Planning Agency
550 Cedar Street
St. Paul, MN 55101

Gene A. Christianson
Chief
Environmental Health Section
North Dakota State Department
of Health
1200 Missouri Avenue
Box 5520
Bismarck, ND 58502-5520

Congressman Dorgan
P. O. Box 2579
Bismarck, ND 58502

Gregg Downing
Minnesota Environmental
Quality Board
110 Capitol Square Building
550 Cedar Street
St. Paul, MN 55101

Pam Dryer
Natural Resources Coordinator
North Dakota Parks and Recreation
Department
1424 W. Century Avenue #202
Bismarck, ND 58501

Shirley Dykshoorn, Director
Office of Intergovernmental
Assistance
14th Floor
State Capitol Building
Bismarck, ND 58501

Milton G. Eckstrom, Jr.
District Office
Congressman Vin Weber
919 South First Street
Willmar, MN 56201

Doug Faiman, Director
Administrative Services Division
North Dakota State Highway
Department
600 E. Blvd.
Bismarck, ND 58505

Mr. Bill Franz
Regional EIS Coordinator
U.S. Environmental Protection
Agency
230 South Dearborn Street
Chicago, IL 60604

Mr. Douglas E. Frisch
Mayor, City of Dumont
Box 12
Dumont, MN 56236

Richard J. Gross
Governor's Counsel
Governor's Office
Capitol Building
Bismarck, ND 58505

Bruce Hagan, Commissioner
North Dakota Public Service
Commission
State Capitol
Bismarck, ND 58505

Pat Hemmy
Area Director, Aberdeen Area
Bureau of Indian Affairs
U.S. Department of the Interior
115 4th Avenue, South East
Aberdeen, SD 57401

Marvis Hogen
Secretary of Agriculture
Anderson Building
Pierre, SD 57501

Howard Jensen
Mayor of Bristol
Box 396
Bristol, SD 57219

Sheila Jimenez
Staff Assistant to
Congressman Tom Daschle
P.O. Box 1536
Aberdeen, SD 57401

Mr. Tom Jorgens, Executive
Director
Northwest Regional Development
Commission
425 Woodland Avenue
Crookston, MN 56716

Mr. Clarence Juelich
City Clerk
Wheaton City Hall
Box 868
Wheaton, MN 56296

Helen Jurchen
NW RDC
425 Woodland Avenue
Crookston, MN 56716

Stuart J. Larson
Soil Conservation Service
Room 324
Federal Office Building
102 N. 4th Street
Grand Forks, ND 58201

Bruce Laughlin
State Representative
Box 375
Finley, ND 58230

Sue Lillwald
Chamber of Commerce
P.O. Box 514
Thief River Falls, MN 56701

Mr. David Maritin
Executive Director
Arrowhead Regional Development
Commission
330 South 1st Avenue, East
Duluth, MN 55802

Al Meyer, Chairman
Traill County Commission
Galesburg, ND 58035

Roger D. Monson
Community Development Corporation
Finley, ND 58230

James R. Myers
Chief of Operations
State Capitol Building
Pierre, SD 57501

Helen M. Ninje
Mayor of Clifford
Garfield and 2nd Street
Clifford, ND 58016

Mr. John Ostrem, Executive
Director
Headwaters Regional Development
Commission
722 15th Street, NW, Box 906
Bemidji, MN 56601

Jack Quinlivan
City Planner
Box 528
Thief River Falls, MN 56701

Mr. Bill Robinson
Single Point of Contact
Program Administrator
Office of Intergovernmental
Assistance
Office of Management and Budget
14th Floor - State Capitol
Bismarck, ND 58505

Glenn Roloff
U.S. Forest Service
1824 N. 11th Street
Bismarck, ND 58501

Mr. Irv Rustad, Director
Lake Agassiz Regional
Planning Council
321 North 4th
Fargo, ND 58102

Dennis Sevigny
Grafton Chamber of Commerce
Box 632
Grafton, ND 58237

Joe Sizer
Assistant Director
Minnesota State Planning Agency
Room 100, Capitol Square Building
St. Paul, MN 55101

Mark Steichen
Deputy Secretary
DWNR
Joe Foss Building
Pierre, SD 57501

Jeff Stingley, Secretary
Department of Game, Fish, and Parks
Anderson Building
Pierre, SD 57501

Dick Tolbers
U.S. Fish and Wildlife Service
50 Park Square Court
400 Sibley Street
St. Paul, MN 55101

Ms. Connie Treidt
Single Point of Contact
State Government Operations
State Capitol Building
Executive Office
Pierre, SD 57501

Mr. Dale Vodehnal
Regional EIS Coordinator
U.S. Environmental Protection Agency
One Denver Place
999 18th Street
Denver, CO 80202-2413

Ken Wald
Office of Planning
Minnesota Department of Natural Resources
500 Lafayette Road
St. Paul, MN 55146

Mr. Julius M. Wangler, Director
Red River Regional Planning Council
P.O. Box 633
Grafton, ND 58237

Gene Wiegand
Urban Planner
City of Aberdeen
P.O. Box 1299
Aberdeen, SD 57401

Jerry Wigness
City Clerk's Office
City of Thief River Falls
Box 528
Thief River Falls, MN 56701

Lt. Col. Bob Wooley
AF REP, FAA
Federal Building
601 E. 12th Street
Kansas City, MO 66106

Area Director, Minneapolis Area
Bureau of Indian Affairs
U.S. Department of the Interior
15 South Fifth Street
Minneapolis, MN 55402

Director
Office of Environmental Project Review
Department of the Interior
Room 4260, Interior Building
18th and C Streets, NW
Washington, D.C. 20240-0001

County Auditor's Office
Day County
710 W. First
Webster, SD 57274

Commissioner
Department of Energy and Economic Development
900 American Center Building
150 East Kellogg Boulevard
St. Paul, MN 55101

East Grand Forks Town Clerk's Office
303 NW 4
E. Grand Forks, MN 56721

Regional Forester
Eastern Region, Forest Service
USDA
Henry S. Reuss Federal Plaza
Suite 500
310 W. Wisconsin Avenue
Milwaukee, WI 53203-2211

Regional Forester
Eastern Region, Forest Service
USDA, Federal Building
P.O. Box 7669
Missoula, MT 59807-7669

Fargo Planning and Development
201 4 Street N
Fargo, ND 58102

Regional Director, Great Lakes Region
Federal Aviation Administration
2300 East Devon Avenue
Des Plaines, IL 60018-4686

Finley City Hall
Finley, ND 58230

First District Association of Local Governments
P.O. Box 1207
Watertown, SD 57201

Grand Forks County Planning Department
Court House
212 S. 4th Street
Grand Forks, ND 58202

Grand Forks Planning Department
404 2 Avenue N.
Grand Forks, ND 58202

Herman Council Board
Town Hall
Herman, MN 56248

Hillsboro City Hall
Hillsboro, MN 58045

Larimore City Hall
122 W. Main Street
Larimore, ND 58251

Mayville City Armory
332 Center Avenue S.
Mayville, ND 58257

Commissioner
Minnesota Department of Agriculture
90 West Plato Boulevard
St. Paul, MN 55107

Commissioner
Minnesota Department of Natural Resources
500 Lafayette Road
St. Paul, MN 55146

Commissioner
Minnesota Department of Transportation
Transportation Building
John Ireland Boulevard
St. Paul, MN 55155

Director
Minnesota Historical Society
Historical Building
690 Cedar Street
St. Paul, MN 55101

Executive Director
Minnesota Pollution Control Agency
1935 West County Road B-2
Roseville, MN 55113

State Planning Director
Minnesota State Planning Agency
100 Capitol Square Building
550 Cedar Street
St. Paul, MN 55101

Moorhead City Clerk
500 Center Avenue
Moorhead, MN 56560

Regional Director, Midwest Region
National Park Service
U.S. Department of the Interior
1709 Jackson Street
Omaha, NE 68102

Regional Director, Rocky Mountain
Region
National Park Service
U.S. Department of the Interior
P.O. Box 25287
Denver, CO 80225

North East Council of Governments
405 Eighth Avenue, NW
Suite 201, Berkshire Plaza
Aberdeen, SD 57401

Northwood City Hall
12 North Raymond
Northwood, ND 58267

Planning and Development
District III
P.O. Box 687
Yanktown, SD 57078

Portland City Hall
702 Arnold Street
Portland, ND 58274

Regional Forester
Rocky Mountain Region, Forest
Service
USDA
11177 W. 8th Avenue
Box 25127
Lakewood, CO 80225-0127

Regional Director, Region 6
U.S. Fish and Wildlife Service
U.S. Department of the Interior
Denver Federal Center
P.O. Box 25486
Denver, CO 80225

Regional Director, Region 3
U.S. Fish and Wildlife Service
U.S. Department of the Interior
Federal Building, Fort Snelling
Twin Cities, MN 55111

Chief
Division of Environmental
Coordination
U.S. Fish and Wildlife Service
U.S. Department of the Interior
Room 402, Hamilton Building
18th and C Streets, NW
Washington, DC 20240-0001

U.S. Fish and Wildlife Service
223 Federal Building
P.O. Box 250
Pierre, SD 57501

Warren City Clerk
126 W. Johnson
Warren, MN 56762

<u>Media, Libraries, and Individuals</u>

Allen Anderson
Box 29
Osnabrock, ND 58269

Arlene and R. G. Anderson
Box 63
Andover, SD 57422

Sheila R. Anderson
RR1, Box 30
Clifford, ND 58016

Duane Bartsch
Manager, Industrial Marketing
Otter Tail Power Company
215 S. Cascade
Fergus Falls, MN 56537

Mr. and Mrs. Leroy Behrens
RR 1, Box 101
Wheaton, MN 56296

Ronald R. Belanus
RR 1, Box 101
Cavalier, ND 58220

Mr. Robert Berg
RR 1, Box 31
Chokio, MN 56221

Mr. and Mrs. Jerry Berger
R. 1, Box 34
Norcross, MN 56274

Brian Bohnsack
RR 1, Box 80
Hillsboro, ND 58045

Arne Boyum, Editor
North Dakota League of Cities
Bulletin
Box 2235
207 E. Broadway
Bismark, ND 58502

Reverend Daniel E. Cole
P.O. Box 435
Thief River Falls, MN 56701

Mrs. Marcie Conroy
RR 2, Box 2
Wheaton, MN 56296

Dorinda Daniel
Box 30
Webster, SD 57274

William C. Davis
Midwest Environmental
Services, Inc.
315 E. Bdy.
P.O. Box 211
Bismarck, ND 58502

William R. Devlin, Editor
Steele County Press
Box 475
Main Street
Finley, ND 58230

Joseph Dill, Editor
The Forum
Box 2020
Fargo, ND 58107

Robert Evanstad
1120 16th Street N
Apt. #4
Fargo, ND 58102

John R. Finnegan, Editor
Pioneer Press
55 E. 4th Street
St. Paul, MN 55101

Mrs. Barbara Frisch
Rt 1, Box 116
Wheaton, MN 56296

Mrs. Gerald Frisch
RR Box 64A
Dumont, MN 56236

Mr. Roger F. Frisch
Felix Frisch & Sons, Inc.
Dumont, MN 56236

Gordon Garnes, Editor
Public Opinion
120 3rd Avenue NW
Box 10
Watertown, SD 57201

William I. Gatheridge
Box 53
Humboldt, MN 56731

Sister MaryLou Geraets
1500 N. Main
Aberdeen, SD 57401

Bernard I. Gill
Box 325
Hillsboro, ND 58045

Marcella Gonsorowski
Route 2
Newfolden, MN 56738

T. J. Gray
Lakehead Pipe Line Co., Inc.
P.O. Box 665
Bemidji, MN 56601

Del Griffin, Editor
American News
124 South Second Street
Box 4430
Aberdeen, SD 57401

Nancy J. Haglund
Route 2
Red Lake Falls, MN 56750

Bill Harbeke, President
First Bank Wheaton
1024 Broadway
Wheaton, MN 56796

Hecla Independent
Hecla, SD 57446

Al Hermodson
Route 3
Crookston, MN 56716

Merle Holdon, Manager
Sheyenne Valley Electric
Cooperative
Box 217
Finley, ND 58230

Floyd Houland
702 4th Ave. E
Ada, MN 56510

Larry Ingalls, Editor
Reporter and Farmer
Box 30
Webster, SD 57274

Mike Jacobs, Editor
Herald
Box 998
Grand Forks, ND 58206

Mr. Joe Kalla
Chairman
Wheaton Community
Development Corporation
Wheaton, MN 56296

Scott Karnik
KXPO Radio
Box 312
Grafton, ND 58237

Ron Kennedy, Manager
Red Lake Electric Coop, Inc.
P.O. Box 430
Red Lake Falls, MN 56750

Mr. Tom Kenville
Jobs Incorporated
413 East Third Street
P. O. Box 514
Thief River Falls, MN 56701

Joel Kramer, Editor
Star Tribune
425 Portland Avenue
Minneapolis, MN 55488

Ron Kyllo
Box 56
Hunter, ND 58048

Maynard B. Laymor
Route 2
Warren, MN 56762

Marvin Lundin, Editor
Thief River Falls Times
P.O. Box 100
Thief River Falls, MN 56701

Gene Lundquist
RR 2, Box 13
Wheaton, MN 56296

Susan MacDonald
KXJB TV
P.O. Box 1397
Grand Forks, ND 58201

Mrs. Thomas K. McAndrews
6435 Margon Avenue So.
Minneapolis, MN 55432

James McKenzie
607 S. 5th Street
Grand Forks, ND 58201

Keith Meyer, Editor and Publisher
Box 49
Hillsboro, ND 58045

George W. Moore, Editor
Tribune
Box 1498
707 E. Front Avenue
Bismark, ND 58501

James A. Morlock, Editor and
  Publisher
Tribune
Box 7
Ipswich, SD 57451

Eugene M. Morton, Editor
Bugle
Main Street
Langford, SD 57474

Charles Naplin
Route 5, Box 82
Thief River Falls, MN 56701

Dan Nilles
Route 2, Box 7
Blanchard, ND 58009

Donald O'Leary, General Manager
Traverse Electric Cooperative,
  Inc.
P.O. Box 66
Wheaton, MN 56296

Lind Osberg, Editor
South Dakota Municipalities
214 E. Capitol Street
Pierre SD 57501

Duane Otto, Manager
Cavalier Rural Electric Coop.
Box 749
Langdon, ND 58249

Mrs. Hattie Phillips
RR 2, Box 13
Webster, SD 57274

Ronald and Gloria Porter
RR 1, Box 63
Grandin, ND 58038

Kenneth Price
Stephen, MN 56757

Larry Rad
Route 3, Box 152
Warren, MN 56762

J. Sanchez
P.O. Box 5548
San Jose, CA 95150

Katherine Satrom, Chairman
North Dakota Workmen's
  Compensation Bureau
Russel Building
Highway 83 N.
Bismarck, ND 58501

Wayne D. Satrom
RR 1, Box 70
Galesburg, ND 58035

Bill Schwalm
Physics Department
University of North Dakota
Grand Forks, ND 58202

Skip Seiser
UPI
P.O. Box 1934
Bismarck, ND 58502

Mr. and Mrs. Carl Simpson
RR 1, Box 133
Tesney, MN 56582

Leon O. Skarperud
220 1st Avenue N.W.
Mayville, ND 58257

Alan G. Smith
RR1, Box 1
Galesburg, ND 58035

Morri E. Spenser, Publisher
Independent
Box 148
Groton, SD 57445

Keith Steva
DIGI-KEY Corp.
701 Brooks Avenue South
Thief River Falls, MN 56701

Ervin Strandquist
Route 2, Box 161
Newfolden, MN 56738

Joe Stroot, Jr.
Box 99
Euclid, MN 56722

Joel Swanson, G.M.
KTRF-KSNR Radio Corp.
P.O. Box 40
Highway 32 North
Thief River Falls, MN 56701

Sally Thompson, Editor
Hillsboro Banner
Box 49
Hillsboro, ND 58045

Ken Tischart
Red Lake Falls, MN 56750

Don Tisher
Box 235
Amherst, SD 57421

Clarice Torgerson
Jobs, Inc.
P.O. Box 514
Thief River Falls, MN 56701

Curtis Twete
Highway 15 West
Melville, ND 58254

Edward Weihand
Box 87
Euclid, MN 56722

Gene Wenstrom
Box 1077
Elbow Lake, MN 56531

Duane Wimpfheimer
Route 1, Box 114
Euclid, MN 56722

Terry Woster, Editor
Capital - Journal
404 E. Sioux Street
Pierre, SD 57501

Terry Woster, Editor
The Times
404 E. Sioux Street
Pierre, SD 57501

Charles Zammert
Box 93
Euclid, MN 56722

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